A vacuum switch for making and breaking an inductive electric circuit is composed of a highly evacuated envelope and a pair of separable electrodes located within the envelope. At least one of the contacts of the electrodes is made of a sintered alloy essentially composed of a metal carbide, such as tungsten carbide, having low work function, another electrically conductive metal, such as silver, which also offers good machining characteristics, and certain wettable materials which allow the silver to impregnate the tungsten carbide by filling in the interstices between the particles thereof. When the contacts are opened, or separated, the resultant heat of an arc initiated therebetween causes the tungsten carbide to emit thermionic electrons which are effective for ionizing the gas, or metal vapors, emanating from the contact surfaces, whereupon the arc is maintained until the first current zero is reached even when only small currents are flowing through the same and chopping problems are generally prevented.

2 Claims, 1 Drawing Figure
The present invention relates to electrical vacuum switches, and more particularly to a vacuum circuit interrupter of the type having a highly evacuated envelope and an enclosed pair of separable electrodes for making and breaking an electric circuit connected in series therewith which possesses improved arc maintenance characteristics in typically low current interruptions.

As is well known, vacuum type switches are widely used as current interrupters in alternating current circuits and in certain oscillation circuits wherein the oscillatory current form is one which typically oscillates between a substantially zero current level and a current level offset from the zero level line.

The electrical vacuum switches referred to herein are of the type normally employed for "switching on and off" operations of an electric circuit involving the inductive loads therein, such as, for example, induction motors, synchronous motors, transformers, induction furnaces and the combination thereof.

Upon the consideration, particularly of the interruption of current in such inductive alternating current circuits employing vacuum switches of the type described having separable main electrodes disposed within an evacuated envelope, it is most important that the actual extinction of the electric arcs maintained between the separated contact surfaces of the electrodes is carried out at a time at which the load current flowing through the electrodes is of substantially zero amplitude. Accordingly, under ideal conditions, after separation of the contacts of an interrupter, an arc should persist until a natural current zero is reached. What has happened in the past, however, is that premature extinction, or "chopping," of the alternating current arc has occurred because of vapor starvation near the electrodes, in certain instances where the load current suddenly falls off or at low current operating levels. This means that the rate of change of the load currents in the inductive circuit is theoretically infinite, and, when such occurs, the electric installations in the circuit may be damaged by a dangerous voltage surge thereby created which is capable of easily destroying the insulations thereof by the product of the higher induced voltages due to the inductances in the circuit and the extremely large rate of change of the currents occurring in the same.

This sudden cutting phenomena of the current flowing through the separated electrodes is referred to as a so-called "chopping" of the load currents, as indicated above, and the current level at which the chopping occurs is referred to as the "chopping current level."

To prevent the breakdown of the insulations in electric machines and instruments connected in the circuit with the vacuum switches, a type of vacuum switch has been provided in which a contact material having a high metal vapor pressure is employed in the arc regions of the electrodes. The representative example of such contact material is an alloy consisting of copper as the major constituent and a substantial amount of bismuth as the minor one, extending to about 20 percent by weight of the entire amount of the contact material.

As indicated hereinafore, in circuits employing these vacuum type switches, the current chopping phenomena is most likely to occur when a load current having a relatively small amplitude, such as, for example, one of 10 amperes, or less, is flowing through the separated electrodes. This results from the insufficiency of the metal vapors in the vicinity of the separated contact surfaces of the electrodes due to a relatively lower energy of lower current arc.

According to our experiences, although the aforesaid alloy of Cu and Bi has the requisite high metal vapor pressure, it has also been found upon examination to cause a higher chopping current level than is desirable in many cases. This unpreferred result is based on a good heat conductivity of the entire contact material, and though the minor constituent, Bi, in the contact material, theoretically functions to reduce the heat conductivity, whenever the arc region of the contact is unable to achieve a higher temperature state because of a low load current, as, for example, 10 amperes or less, such a contact material has always shown the higher chopping current levels which are usually associated with higher level surge voltages that cause damage to the insulations in the electrical installations connected to the vacuum switches.

Besides, there are other significant problems in such vacuum type switches heretofore available and designed for reducing the chopping current level by employment of electrode contact surfaces having high metal vapor pressures.

In the first place, it will be readily appreciated that the arc region of the electrodes may be quickly consumed due to the extremely high temperature arcs which are initiated between the contact surfaces of the electrodes during each current interruption, and which accompany the evolvement, or giving off, of the positive evaporations of the metal vapors. As is well known, these vacuum type switches are usually employed so as to cause switching on and off of their accompanying circuits, for example, in an electric motor energization circuit, with high frequency of use. To this end, the electrodes are likely to be consumed in an extremely short period of time, thereby shortening the effective life of the vacuum switch.

Also, the higher temperature of the electric arc is likely to cause the electrode to melt, and then spatter down into the envelope of the vacuum switch. As a result, the consumption of the electrode will occur even more rapidly than might be expected from the aforesaid evaporation, whereby additional shortening of the life of the electric vacuum switch occurs.

This spattering and melting of the electrodes may make many concaves on the contact surfaces of the electrodes, and thus there may be made some sharp edges at the peripheral portions of the concaves, whereby the dielectric strength of the vacuum between the separated electrodes will be reduced. In accordance with our experiences, the dielectric strength of the vacuum type switch is reduced from the initial value to 60 percent of that value after being subjected to several current interruption tests. This means that such switches must be produced which are capable of withstanding voltages higher by more than 40 percent of the voltage ratings thereof, and this involves an expensive manufacturing process. Finally, because the
positive evaporation of the contact material to provide higher metal vapor pressures are carried out with each opening cycle of the electrodes, the amount of the minor constituent, Bi, involved in the contact material is gradually decreased, thereby gradually increasing the chopping current levels in response to the number of times the "switching off" operation is performed.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a vacuum type switch having separable electrodes within a highly evacuated envelope in which at least one of the electrodes includes an improved contact material at its contact surface, which material is not characteristic of higher metal vapor pressures than conventional materials heretofore employed, yet which maintains an electric arc between separated electrodes when the electrodes are separated to open an electric circuit connected to the switch gear.

Another object of the present invention is to provide an electric vacuum switch having separable electrodes within a highly evacuated envelope which possesses improved arc maintenance characteristics in low current interruptions.

In accordance with a preferred embodiment of the present invention, the foregoing and other objects are achieved by providing a pair of separable electrodes positioned within a highly evacuated envelope so as to be capable of making and breaking an electric circuit in which they are connected. A contact surface on at least one of the electrodes is preferably made of a sintered alloy including a mixture of a body of metal carbide having a low work function and at least one kind of wettable material being composed of nickel, copper and cobalt in preselected ranges as will be set forth in the following description. The sintered alloy is impregnated with at least one type of electrically higher conductive metal by an amount of sufficient proportion capable of improving the electric conductivity and machining characteristics of the entire contact material including said body of metal carbide.

BRIEF DESCRIPTION OF THE DRAWING

Other objects and many of the attendant advantages and features of the present invention will be readily appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawing, wherein the sole FIG. shows an elevational sectional view of an electrical vacuum switch constructed in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawing, there is shown an electrical vacuum switch generally indicated by the reference numeral 10. As is well known, the vacuum type switch conventionally comprises a highly evacuated envelope 11 having a cylindrical side wall 12, which may be made of any suitable insulating material, such as, for example, glass, ceramics or the like, and a pair of separable contacts 13 and 14 made of an improved material according to the present invention and located within the envelope. One of the contacts 13 is stationary and is secured to an inner end of a stationary electrode 15, the end of which extends through a metallic end cover, or plate 16 located on an upper peripheral portion of the cylindrical side wall 12. A vacuum-tight seal member 17 is provided between the peripheral portions of the end cover 16 and one of the open ends of the insulating side wall 12. The portion of the end cover 16 through which the stationary electrode 15 extends is vacuum-tightly sealed off by any suitable sealing means, such as a weld. The uppermost end of the stationary electrode 15 is connected with a conductor, which, in turn, is connected to an A.C. power supply (not shown).

The other contact 14 is a movable one, which is securely mounted on an inner end of a movable electrode 18, the other end of which is connected to an A.C. conductor of an A.C. load circuit located outside of the envelope, as well as to a driver which acts to reciprocably move the electrode 18 and the contact 14 between positions which are alternately close to and separate, or further away, from the stationary contact 13. Similarly, as described above, there is provided a vacuum-tight seal member 19 for vacuum-tightly sealing the envelope 11 between the peripheral portions at the other open end of the cylindrical side wall 12, opposite the cover 16, and a separate cover, or plate, 20. The plate has an opening 21 through which an outer end of the movable electrode 18 slidesably extends out of the envelope 11. To vacuum-tightly seal off the opening 21 through which the movable electrode extends, a flexible metallic bellows 22 is a vacuum-tightly secured at one end thereof to the edge portion of the opening 21, and the other end of the bellows 22 is vacuum-tightly connected to the movable electrode 18 through a sealing cap member 23.

The vacuum type switch constructed in accordance with the present invention is not intended to rely solely upon the utilization of function due to the higher metal vapor pressure to maintain an electric arc 25 occurring between the separated contacts 13 and 14 when the device is switched off for interrupting the current flowing in the switch circuit. However, where the contacts are opened for "switching off," or interrupting the current flow, there will occur certain metal vapors between the separated contacts which arise from the composition of the contact material as explained hereinafter. These metal vapors will, however, be diffused into the vacuum space around the arc and thereby eventually result in final extinction of the arc. At the same time, vapor deposition on the surface of the bellows, which might cause injury to the mechanical characteristics of the bellows, is prevented by the cap type seal 23 which effectively prevents the deposition of the vapors on the surface of the bellows through its specific sealing arrangement.

On the other hand, a part of the aforesaid vapors might be deposited on the inner surface of the side wall 12 which is made of insulating material. This may result in the lowering of the dielectric strength along the axial direction of the side wall. To avoid this defect, there is arranged a cylindrical shield member 24 around the contact area and isolated from the inner surface of the side wall 12 and the contacts 13 and 14, respectively. Thus, the shield 24 will catch the metal vapor particles randomly directed toward the inside wall of the en-
velope 11, and effectively preventing the aforesaid lowering of the dielectric strength of the envelope wall. In the drawing, there is shown an open status for contacts 13 and 14, thereby to define a gap therebetween for isolating the load circuit from the source.

When closing of the contacts 13 and 14 is required, it is only necessary to move the movable electrode 18 with the movable contact 14 upwardly by means of the driver, not shown, whereupon the bellows 22 will become elongate to make the contacts without any breakdown of the vacuum in the envelope. On the contrary, where it is necessary to separate the contact 14 from the contact 13, the driver will drive the electrode 18 downwardly, thereby causing the separation of the contact 14 from the contact 13. In the latter case, there will occur a shrinkage on the bellows and an electric arc 25 having an extremely higher energy will be initiated, as well as be drawn out, between the separated contacts.

As pointed out, the arc includes substantial metallic particles which are evaporated from the contact surfaces and possess good electric conductive characteristics for normally maintaining the arc even at low current levels. However, these metallic particles or vapors will rapidly diffuse into the vacuum atmosphere around the arc, causing it to be extinguished quickly whenever the current is fully interrupted, which normally occurs at or close to the first current zero in the applied alternating current wave form.

According to the preferred embodiment of the present invention, the contact material is made of a sintered alloy comprising silver (Ag) and tungsten carbide (WC).

In the manufacture of the contact material, initially, there is prepared for the compositions of the material in order to obtain the end constituents for the contacts 13 and 14, a mixture as follows:

Ni—0.1 to 5 weight by percent
Cu—0.1 to 1 weight by percent
Co—0.1 to 5 weight by percent
Ag—10 to 60 weight by percent
Free Carbon—less than 0.05 weight by percent
WC—the remainder

Tungsten carbide (WC) has the characteristic of a low work function, that is, it possesses higher thermionic electron emission characteristics, and besides, it is a kind of refractory material. As is well known, tungsten carbide (WC) is also difficult to machine for making the contacts.

Ni, Cu, and Co are the wettable materials for the tungsten carbide (WC), and they operate to improve the wettable characteristics of the tungsten carbide (WC) so as to make capable easier impregnation of the Ag into the WC in every nook and corner, or among the interstitial spaces, thereof.

First, as is usually done, the powdered WC, Ni, Cu and Co are mixed, and then they are sintered to make a sintered alloy. Then, the resultant sintered alloy is located within an exhausted atmosphere, and either sunk in a bath filled with the molten silver or has the base portion thereof immersed in the molten silver.

Thus, the molten silver can be impregnated among the particles of tungsten carbide to fill therewith all of the interstitial spaced among them. The aforesaid wettable materials greatly contribute to this impregna-

tion process. In accordance with our repeated tests, this good state of the impregnation has been confirmed in the fact that the resultant contact material has not shown the emanation therefrom of the ionizable gases which might have existed among the WC particles when the contact material has suffered from the higher temperature of electric arcs.

The examinations, or tests, on the current chopping level have been carried out more than 30 times per each pair of electrodes with 10 amperes. The chopping current level is the current amplitude at which the chopping phenomena occurs and it varies with each test. Usually the maximum value out of many test datum, for example, more than 30, is adapted as the current chopping level of the electrodes. The electrodes under these tests had the dimensions of 22 mm. diameter, 5 mm. thickness and 25 mm. diameter, 5 mm. thickness.

As the result, a sintered alloy including 30 percent by weight of Ag, has given a chopping level between 1.1 A. and 2.0 A. On the other hand, another alloy including 40 percent by weight of Ag has shown a chopping level between 1.9 A. and 3.2 A. Besides, a further WC alloy including 55 percent by weight of Ag has shown levels between 2.4 A and 4.2 A.

It can be thus seen that the less Ag present by percentage of weight, the smaller will be the chopping current levels of the WC alloy.

Accordingly, it is desirable to reduce the amount of silver to be impregnated within the sintered tungsten carbide (WC) alloy in order to reduce the chopping current level. However, we have found that the contact material becomes harder to machine as the amount of silver impregnated in the sintered WC alloy is decreased. In accordance with our experiences, when the contents are less than 10 percent by weight of Ag in the sintered WC, it is impossible to carry out the required machining process of the contact material because of the occurrence of breaks in the cutting tool for the material. On the other hand, when the contents of Ag in the sintered WC are more than 60 percent by weight, another defect arises in that the contact material exhibits a higher chopping current level. This results from the reason that it is difficult to maintain the electric arc between the separated contacts because of the lower temperature involved due to smaller current conditions. Such a lower temperature rise also results from the higher heat conductivity of the silver.

The silver impregnated within the sintered WC in accordance with the present invention functions to improve the electric conductivity of the sintered alloy.

When the electrodes 15 and 18 having the contacts 13 and 14 are separated in order to interrupt the electric circuit, an electric arc 25 is initiated between the separated contacts; and then it makes temperatures of the contact surfaces rise to cause the cathode spots on the contact surfaces from which may be emanated the thermionic electrons. As mentioned above, the WC has a low work function, so that even though the currents flowing through the arc initiated between the separated contacts have smaller amplitudes, there will nevertheless occur an emission of the thermionic electrons sufficient to ionize the smaller amounts of silver vapor which exist between the separated contacts.
To this end, there will be positively maintained an arc having smaller current levels between the separated contacts until the current has fallen to a minimum level which will not cause chopping of the current to the electric circuit in which the vacuum switch is connected. In this way, perceptible surge voltages do not occur in the circuit to destroy the insulations of the electric installations connected thereto.

Likewise, in accordance with the present invention, no concaves are created on the contact surface during the existence of the electric arc because the contacts are mainly made of a refractory material, WC. Accordingly, any lowering of the dielectric strength between the separated contacts due to the concaves does not occur with this invention. Further, even though some amounts of silver impregnated in the contact material are evaporated due to higher temperatures suffered from the arc, the low work function characteristics of the contact material does not vary, and to this end the rising of the chopping current levels does not occur, such as might have occurred in the prior vacuum type switch contact.

It is to be understood that modifications may obviously be made by substituting other types of contact materials, for example, Cu and WC. The contact made of the sintered alloy including Cu and WC (40 percent by weight being Cu) has shown a chopping current level of 4.2 A, which is higher than those of the sintered alloy including Ag and WC. This is because the low work function of the Ag is extended over a range between 3.08 to 3.56 eV, while on the other hand the low work function of the Cu is extended over the other range between 3.85 to 4.38 eV, and the values of the latter are higher than those of the former. Further, the vapor pressure of the Ag is higher than that of the Cu, comparing at the same temperature.

Also, it should be readily apparent that the low work function material WC may be replaced by MoC, ZrC, TiC, VC and SiC, as well as the combinations of these. It should be further noted that the amount of the free carbon involved in the contact material is preferably less than 0.05 percent by weight for the purpose of preventing the lowering of the wettability characteristics of the contact material.

Obviously, many modifications and variations of the present invention are possible in light of the teachings herein. It is understood, therefore, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed and desired to be secured by Letters Patent is:

1. In a vacuum type switch for maintaining an arc at low current levels comprising a highly evacuated envelope and a pair of separable contacts located in the envelope so as to make and break an electric circuit, the improvement comprising:
   at least one of the separable contacts being formed of a sintered metal carbide being selected from a group consisting of WC, MoC, ZrC, TiC, VC, SiC, and the combinations thereof, and including a wettable material composed of 0.1 to 5 percent by weight of Ni, 0.1 to 1 percent by weight of Cu and 0.1 to 5 percent by weight of Co, the sintered metal carbide further being impregnated with an electrically conductive metal amounting to between 10 and 60 percent by weight of the total weight of said sintered metal carbide, said wettable material and said electrically conductive material.

2. In a vacuum type switch according to claim 1, said electrically conductive material being silver (Ag).