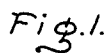
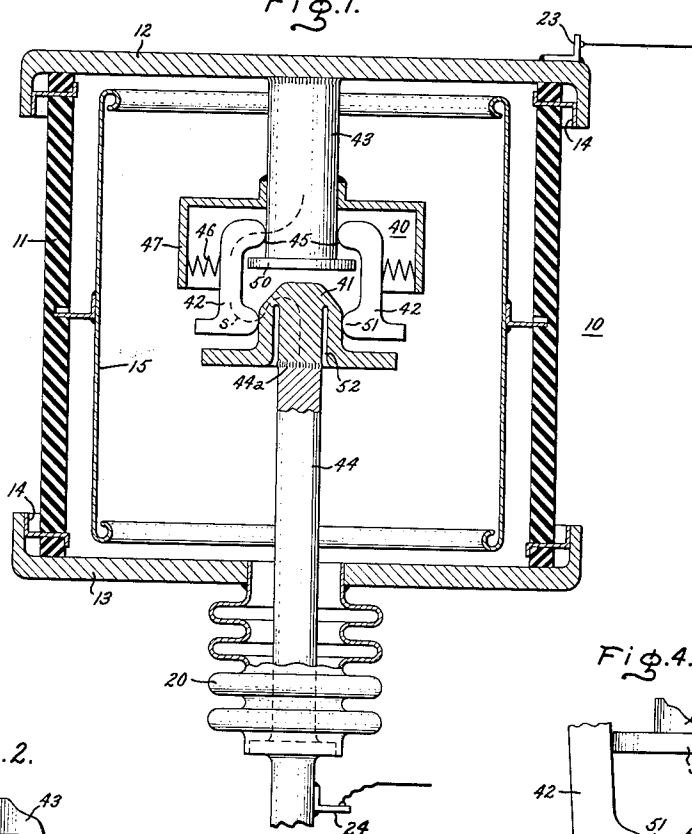


Nov. 7, 1961

T. H. LEE
CONTACT STRUCTURE FOR A VACUUM-TYPE
CIRCUIT INTERRUPTER
Filed June 15, 1960

3,008,022



* Fig. 2.

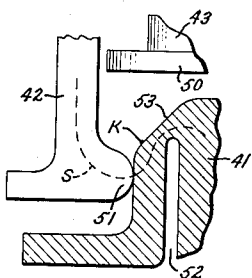


Fig. 3.

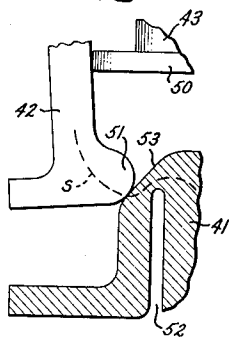


Fig. 4.

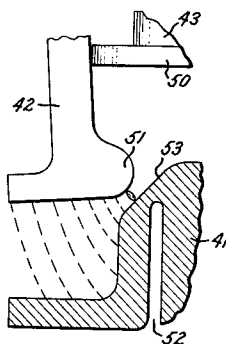


Fig. 6.

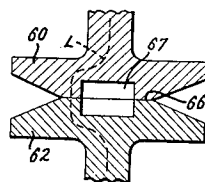
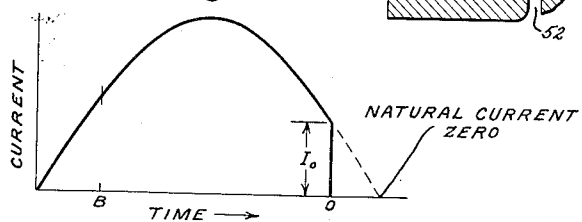


Fig. 5.



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3,008,022

CONTACT STRUCTURE FOR A VACUUM-TYPE CIRCUIT INTERRUPTER

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Filed June 15, 1960, Ser. No. 36,373
16 Claims. (Cl. 200-144)

This invention relates to an electric circuit interrupter of the vacuum type and, more particularly, relates to contact structure for such an interrupter. Although the invention is especially concerned with sliding contact structure, certain of its broader aspects apply also to butt-type contact structure.

Heretofore, the opposing contacts of vacuum interrupters have generally been designed in such a manner that there is little or no sliding action between the two contacts. In other words, the contact design has generally been of the butt-type. Probably the most important reason that sliding type contacts have been avoided is that the surfaces of vacuum interrupter contacts are extremely clean, and frictional engagement of clean metal surfaces in a high vacuum ordinarily produces destructive galling or seizure between the two surfaces.

There are, however, certain exceptional combinations of metals which have a high resistance to seizure or galling even under high-vacuum, clean-surface conditions, e.g., combinations of certain metals which are immiscible in each other, such as silver and iron. In view of the high seizure resistance of such metal combinations, it is possible to materially reduce the seizure and galling problems of sliding contacts in a vacuum interrupter by forming one of the sliding contacts of silver and the other of iron.

But even such contacts are subject to a number of basic difficulties. One such difficulty arises from the tendency of arcing to transfer metal from one contact to the other. In the usual contact arrangement, the eventual result of such metal transfer would be that after several operations, sliding between the two contacts would bring like metals into engagement. When these surfaces of like metals slide on each other, seizure and galling are likely to occur therebetween if the coatings constituting these surfaces are of significant thickness.

Another difficulty that is encountered with a silver-iron pair of contacts in a vacuum circuit interrupter is that these contacts have an excessive tendency to "chop" under low current conditions. By "chopping" is meant the abrupt and premature cut-off of current flowing through the arc between the contacts before a natural current zero is reached. This sharp drop in current can generate extremely high voltages across any inductive device connected in circuit with the interrupter, and such overvoltages can lead to destruction of the inductive device.

Accordingly, an object of my invention is to provide, for a vacuum interrupter, sliding contacts that are capable of being repeatedly opened and closed in an energized alternating current circuit without destructive galling or seizure and yet which do not produce excessive current chopping at low currents.

In carrying out my invention in one form, I provide a pair of sliding contacts in which the sliding surfaces of the two contacts are constructed of materials that are immiscible in each other. These contacts are separable to establish circuit interrupting arcs between predetermined regions of said sliding surfaces. Arcs above a predetermined current value will transfer an appreciable amount of metal between the contacts, but I prevent such transferred metal from accumulating on the sliding surfaces in a quantity sufficient to interfere with free

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sliding by providing magnetic means which is effective to drive these relatively heavy current arcs off of said sliding surfaces and is effective to force arc-generated metal vapors away from said sliding surfaces. In the region of each sliding surface where arcs are initiated, the contact material includes a metal having a vapor pressure at least as high as that of tin at temperatures in excess of 2000° K. The high vapor pressure metal is present in sufficient quantity to consistently hold the current chopping level to a value of no more than 4 amperes, even when interrupting currents of less than 50 amperes peak value. The high vapor pressure metals of the two contacts are dissimilar and are immiscible with each other and with the remaining constituents of the other contact material. Moreover, all possible combinations of the constituents of the opposed contacts contain at least one metal from the B-subgroup of the periodic table. This immiscibility between the constituents of the opposing contacts and this B-subgroup relationship result in a high resistance to seizure, while the high vapor pressure constituent holds the current chopping level to an acceptable value. The action of the magnetic means maintains the high resistance to seizure unimpaired through repeated operations of the interrupter. A specific example of a contact arrangement constructed of materials meeting the above requirements for immiscibility, B-subgrouping, and for high vapor pressure is a sliding contact arrangement in which one of the contacts is a solid solution alloy of silver and cadmium containing about 15% cadmium and the other is a mixture of iron and bismuth containing about 20% bismuth.

In its broader aspects, the present invention is applicable to butt-type contacts, as well as sliding contacts. In this regard, the tendency of butt-type contacts to weld together under certain heavy current conditions can be lessened by forming the contact-making regions of the butt-type contacts of the materials set forth in the preceding paragraph and by providing magnetic means for driving high current arcs off of the contact-making surfaces to preclude an appreciable amount of metal from being transferred by arcing onto each of the contact-making surfaces from the opposed contact.

For a better understanding of my invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a sectional view of a vacuum-type interrupter containing sliding contact structure embodying one form of my invention.

FIG. 2 is an enlarged view of a portion of the sliding contact structure contained in the interrupter of FIG. 1. The contacts of FIG. 2 are shown in their fully closed position.

FIG. 3 is an enlarged sectional view of the sliding contacts shown in a position through which they pass at the approximate instant at which an arc is first drawn between the contacts.

FIG. 4 is a sectional view of the contact shortly after they have separated during an opening operation.

FIG. 5 is a graphic representation illustrating the current-chopping phenomena referred to hereinabove.

FIG. 6 shows a butt-type contact arrangement embodying certain aspects of the invention.

Referring now to the interrupter of FIG. 1, there is shown a highly evacuated envelope 10 comprising a casing 11 of suitable insulating material and a pair of metallic end caps 12 and 13 closing off the ends of the casing. Suitable seals 14 are provided between the end caps and the casing to render the envelope 10 vacuum-tight.

The internal insulating surfaces of casing 11 are protected from the condensation of arc-generated metal vapors thereon by means of a tubular metallic shield 15 suitably supported on the casing 11 and preferably elec-

trically isolated from both end caps 12 and 13. This shield acts in a well-known manner to intercept arc-generated metallic vapors before they can reach the casing 11.

The normal pressure within the envelope 10 under static conditions is lower than 10^{-4} mm. of mercury and is preferably in the range of 10^{-5} to 10^{-8} mm. of mercury. Such pressures assure that the mean-free path of electrons emitted from the high voltage parts of the interrupter will be longer than the potential breakdown paths in the interrupter.

Located within the envelope 10 is a set of separable sliding contacts 40 and 41 shown in FIG. 1 in their engaged or closed circuit position. The contact structure 40 is a socket-type stationary contact assembly, and the contact structure 41 is a plug-type contact movable into and out of engagement with the socket-type stationary contact 40. The stationary contact assembly 40 is supported by means of a stationary conductive rod 43 integrally united at its upper end with the end plate 12. The movable plug contact 41 is brazed at 44a to a longitudinally-movable conductive rod 44 that extends through an opening in the lower end plate 13. A flexible metallic bellows 20 provides a seal about the operating rod 44 to allow for vertical movement of the rod without impairing the vacuum inside the envelope 10. As is shown in FIG. 1, the bellows 20 is secured at its respective opposite ends to the operating rod 44 and the end caps 13.

Coupled to the lower end of the operating rod 44, there is provided suitable actuating means (not shown) which is capable of driving the movable contact 41 downwardly out of engagement with the stationary contact 40 so as to open the interrupter and which is capable of returning the contact 41 to its illustrated position so as to close the interrupter.

For connecting the interrupter in an alternating power circuit, suitable terminals, schematically illustrated at 23 and 24, are provided. The upper terminal 23 is electrically connected to the upper contact 40 through the conductive parts 12 and 43, and the lower terminal 24 is connected to the lower contact 41 through the conductive operating rod 44. When the interrupter is in its closed position of FIG. 1, current can flow between terminals 23 and 24 through the engaged contacts 40 and 41.

The stationary contact assembly 40 comprises a plurality of fingers 42 circumferentially spaced about the stationary conductive supporting rod 43. Each of the fingers 42 has a pivot surface 45 adjacent its upper end bearing against the supporting rod 43. Suitable compression springs 46 disposed between a stationary cylinder 47 and the fingers 42 urge the pivot surfaces 45 into firm current-carrying engagement with the stationary rod 43 and also urge the lower ends of these fingers 42 in a direction toward each other. A suitable annular stop 50 carried by the stationary rod 43 and disposed between the fingers 42 limits the motion of the fingers 42 in a direction toward each other when the fingers are not in engagement with the plug contact 41. The plug contact 41 is telescopically received between the fingers 42, and when the interrupter is closed, as shown in FIGS. 1 and 2, the springs 46 urge the projections 51 at the lower ends of the fingers 42 into firm current-carrying engagement with the outer periphery of the plug contact 41. Thus, current flows through the interrupter via a conductive path extending from rod 43 through the fingers 42 to the plug contact 41.

Referring to FIGS. 1 and 2, it will be noted that the movable plug contact 41 has a longitudinally-extending, continuous annular groove 52 formed therein. This groove 52 extends upwardly from the lower end of contact 41 a substantial distance past the points at which the fingers 42 engage the contact 41, thus forcing the current flowing through the contacts via any individual finger 42 to follow an S-shaped path, such as shown by the dotted line S in FIGS. 1 and 2. This path extends upwardly from the rod 44 past the top of groove 52, then radially outward

into the tubular portion of contact 41 and then through the point of contact-engagement via a downwardly-bowing, loop-shaped route. It should be noted that the groove 52 extends upwardly past not only the point of contact-engagement shown in FIG. 2 but also past the point on the plug contact 41 at which contact-part occurs during a circuit-opening operation. This point, which is designated K in FIG. 2, corresponds to the point of contact-engagement shown in FIG. 3, where the contacts are shown just prior to the instant of contact-part. Since the groove 52 extends past the point K, it should be apparent that the current path S still contains the downwardly-bowing loop extending through the point of contact-engagement at the instant of contact-part. In some cases, it is possible to provide enough of a loop-shaped configuration even with a groove that terminates just short of the point K, but it is generally preferred that the groove extend past point K, as illustrated. The significance of the loop-shaped configuration of the current path will soon appear more clearly.

When the plug contact 41 is driven downwardly to open the circuit interrupter, the fingers 42 of the socket contact 40 slide on the outer peripheral surface of the plug contact 41 until the tapered portion 53 of the plug contact 41 has entered the position shown in FIG. 3. Due to the inwardly acting forces applied by the springs 46 and due to the magnetic forces of attraction urging the fingers 42 toward each other, the fingers 42 had remained in engagement with the tapered portion of the plug contact 41 during downward opening movement of the plug contact 41 just prior to entry into the position of FIG. 3. But upon entry of the plug contact 41 into the position of FIG. 3, the fingers 42 encounter the stop 50, and further inward movement of the fingers 42 is thereby blocked. Accordingly, further downward motion of the plug contact 41 past the position of FIG. 3 toward the position of FIG. 4, brings a reduced diameter portion of the plug contact 41 into alignment with the projections 51 on the finger contacts 42, thereby opening a gap of progressively increasing size between the finger contacts 42 and the plug contact 41, as is shown in FIG. 4. The arc that is established across this gap persists until about the time a natural current zero is reached, after which it is prevented from reigniting by the high dielectric strength of the vacuum, thus resulting in circuit interruption. The behavior of the arc prior to current zero will soon be described in greater detail.

Closing of the circuit interrupter is effected by returning the plug contact 41 progressively through the positions of FIGS. 4 and 3 to its position of FIG. 2. This closing operation, like opening, results in sliding of the finger contacts 42 on the outer periphery of the plug contact 41.

Heretofore, the opposing contacts of vacuum interrupters have generally been designed in such a manner that there is little or no sliding action between the two contacts. In other words, the contact design has generally been of the butt-type. Probably the most important reason that sliding-type contacts have been avoided is that frictional engagement of clean metal surfaces in a high vacuum ordinarily produces destructive galling or seizure between the two surfaces. In this regard even the smoothest of surfaces contains microscopic projections, and when one surface slides over the other, these projections contact each other and tend to weld together. In a vacuum interrupter, such as described hereinabove, these projections are free of all surface film and completely bare, and this greatly increases the tendency of these projections to weld together and produce extremely high coefficients of friction.

Despite the high coefficients of friction which ordinarily exist between clean sliding surfaces in a high vacuum, there are certain combinations of metals between which a relatively low coefficient of friction is present even under these extreme conditions, e.g., a combination of silver and iron. The explanation of the low

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coefficient of friction for particular combinations such as silver and iron is based upon the fact that the metals of these combinations are practically immiscible with each other at solid state temperatures and at least one of the metals is from the B-subgroup of the periodic table. For example, silver and iron are immiscible, and silver is a B-subgroup metal. This immiscibility helps to lessen the tendency to form welded junctions between the tips of surface irregularities and further helps to weaken the junctions that are formed. The B-subgrouping contributes in an important manner to weakness in the junctions that are formed because the bond between B-subgroup metals and others tends to be less metallic and hence more brittle and weaker than the bond between A-subgroup metals. Because the junctions between immiscible metals are relatively weak and few in number, assuming one of the metals is a B-subgroup metal, such junctions can be easily sheared at the interface of the projections and therefore do not create excessive frictional resistance.

In view of the low coefficient of friction between immiscible metals such as silver and iron, it is possible to materially reduce the galling and welding problems of sliding contacts in a vacuum by forming one of the sliding contacts of silver and the other of iron.

But even such contacts are subject to a number of basic difficulties. One difficulty is that arcing tends to transfer metal from one contact to the other, with the eventual result being that after several operations sliding between the two contacts brings like metals into engagement. With these surfaces of like metals slide on each other, seizure and galling are likely to occur between the two surfaces if the coatings constituting the surfaces are of significant thickness. In the disclosed embodiment of the invention, I have overcome this problem by forcing all but the lightest current arcs off of the sliding regions of the contacts before they can cause a significant amount of transferred metal to accumulate on the sliding surfaces. This is accomplished by relying upon the magnetic effect of the downwardly-bowing loop-shaped portion of the current path S extending through the arc initiation region, as is shown in FIG. 3. The magnetic effect of this loop-shaped path is to lengthen the loop, and, thus, drive the arc downwardly and radially outwardly off of the region where the arc is initiated. The higher the current, the greater will be the arc-propelling force. Thus, heavy and medium current arcs will be quickly driven radially-outward through the approximate positions indicated by the dot-dash lines of FIG. 4 onto the outer peripheral regions of the contacts 40 and 41. Only light current arcs, e.g., below about 100 amperes, will remain behind in the region immediately adjacent the point of arc-initiation. These arcs remain behind because with light currents the magnetic force on the arc is low and of insufficient magnitude to drive the arc an appreciable distance radially-outward before the first current zero is reached. Allowing light current arcs to remain near the arc initiation region is not a significant disadvantage because a light current arc transfers an insufficient amount of metal between the contacts to materially interfere with free sliding action between the contacts during subsequent opening and closing operations.

Another difficulty that is encountered with a silver-iron pair of circuit interrupting contacts in a vacuum interrupter is that for most circuit applications these contacts have an excessive tendency to "chop," i.e., to force the current flowing through the arc abruptly and prematurely to zero before a natural current zero is reached. For high and medium current interruptions, for example, above 500 amperes, the arc usually persists until a natural current zero is reached. But for low current interruptions, the arc frequently does not persist until a natural current zero. The interrupter usually quenches the arc ahead of natural current zero and, thus, "chops"

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the current flowing between the contacts, i.e., forces this current abruptly and prematurely to zero before the natural current zero is reached.

This chopping action is illustrated in FIG. 5, where the current flowing between the contacts is plotted against time. It can be assumed that the contacts are parted to establish an arc at an instant depicted at B. The arc is maintained up until about the instant 0 and, hence, the current is free to follow substantially its natural curve up until this instant. At the instant 0, however, the current is forced abruptly and prematurely to zero before the natural current zero is reached. It is this action which is referred to throughout this application as "chopping." The amount of current chopped is designated I_0 and this quantity is referred to hereinafter as the "chopping current."

As pointed out hereinabove, the sudden change in current which accompanies chopping induces across any device in the circuit a voltage having a magnitude varying directly with the surge impedance of the device. Inductive devices typically have surge impedances on the order of thousands and even hundreds of thousands of times greater than the surge impedances of the usual capacitive and substantially fully-resistive loads. If the vacuum interrupter is to be used in circuit with typical inductive loads of this nature, the chopping current must be held to a very low value if the generation of excessive over-voltages is to be avoided.

For many inductive loads, the maximum value of chopping that can be tolerated is about 4 amperes. For many others the maximum acceptable values are as low as three and even two amperes. The present invention is primarily concerned with providing vacuum interrupters that are capable of being applied to inductive loads such as these, though in certain of its broader aspects, the invention is concerned with interrupters that are intended for use in circuits where slightly higher chopping currents can be tolerated.

In my joint application with J. D. Cobine, Serial No. 750,784, now Patent No. 2,975,256, filed July 24, 1958, and assigned to the assignee of the present invention, there are set forth certain criteria that can be utilized for selecting contact materials capable of consistently holding the chopping current to acceptable levels, even when interrupting currents under 50 amperes peak value. For example, it is pointed out in the Lee et al. application that the current-chopping level can consistently be held to no more than 4 amperes, even when interrupting currents under 50 amperes peak value, if the material of the arcing region (1) has a low chemical affinity for oxygen in comparison to that of aluminum, magnesium, and calcium; (2) is free of sorbed gases and contaminants, and (3) comprises a metal having a vapor pressure at least equal to that of tin at temperatures exceeding 2000° K. and a thermal conductivity less than that of copper and silver if the metal is one having characteristic vapor pressures generally equalling or lower than those of silver for given temperatures. Examples of materials meeting these requirements are tin, antimony, indium, lead, zinc, manganese, and bismuth.

It is unnecessary that the material be composed entirely of one of these metals. An alloy or mixture containing such a metal is adequate providing the metal is present in sufficient proportions to consistently hold the current-chopping level, even when interrupting currents of less than 50 amperes peak value, to the acceptable maximum value, which, in the assumed case, is 4 amperes.

With reference to the requirement that the material be free of sorbed gases and contaminants, the extent of such freedom should be such that if the material is placed in a vacuumized test chamber a few litres in volume and then deeply eroded by repeated electric arcing, the pressure level in the chamber a few cycles after arcing will

remain at least as low as its initial value, even in the absence of getters and pumps and even if the initial pressure in the chamber is on the order of 10^{-5} mm. of mercury. The contacts of my interrupter, at least in their arcing regions, are free of sorbed gases to this extent.

If the maximum permissible chopping level is lower than 4 amperes and is as low as, say, 2 amperes, then acceptable chopping performance can be obtained by utilizing for the arcing region a material which meets all of the above requirements and which, in addition, contains as its high vapor pressure metal constituent a metal having characteristic vapor pressures at least as great as those of lead. Examples of metals in this category are lead, bismuth, and antimony. If this high vapor pressure metal is combined or alloyed with some other metal, the high vapor pressure metal should be present in sufficient proportions to consistently hold the current-chopping level, even when interrupting currents of less than 50 amperes peak value, to the acceptable maximum value, which in this assumed case is 2 amperes.

To overcome the chopping problem with sliding contacts made from lower vapor pressure metals such as silver and iron, I alloy the silver that is used for one of the contacts with a first high vapor pressure metal that is immiscible in iron and alloy the iron that is used for the other contact with a second high vapor pressure metal that is immiscible in both silver and the first high vapor pressure metal. For example, as the first high vapor pressure metal, I use cadmium, and as the second high vapor pressure metal, I use bismuth. Thus, one of the contacts is formed of a silver-cadmium alloy, and the other contact is formed of an iron-bismuth alloy, or mixture. The cadmium in one of the contacts produces sufficient vapor pressure during low current arcing (under 50 amperes peak value) to hold the current-chopping level to an acceptable value under 4 amperes when that particular contact acts as the cathode, and the bismuth in the other contact produces sufficient vapor pressure during this low current arcing to hold the current chopping level to an acceptable value when this particular contact acts as the cathode. Because cadmium is immiscible with both iron and bismuth and is a B-subgroup metal, it forms no strong welded junctures with either the iron or the bismuth of the other contact and, thus, introduces no appreciable friction problems. Similarly, since the bismuth additive is immiscible with both silver and cadmium and is a B-subgroup metal, it forms no strong welded juncture with either the silver or cadmium of the other contact, and, thus, introduces no appreciable friction problems. A suitable silver-cadmium alloy is a solid solution alloy containing 15% cadmium, and a suitable iron bismuth mixture is one containing about 20% bismuth.

In the disclosed interrupter, the finger contacts 42 are formed of the silver-cadmium alloy described above, whereas the plug contact 41 is formed of the iron-bismuth mixture described above. It is to be understood, however, that iron-bismuth might equally well be used for the finger contacts, and silver-cadmium for the plug contacts. The supporting rod 43, or at least its bearing surface that receives the finger contacts, is constructed of a metal that has a high seizure resistance with respect to the metals of the finger contacts. For example, iron is preferably used for the bearing surface of rod 43 if the finger contacts are of silver-cadmium.

Although it is preferred that both of the sliding contacts be formed of a material containing a high vapor pressure constituent, it is permissible in certain exceptional cases to utilize such a material for only one of the contacts. One such case is that in which it can be predetermined that only a certain one of the contacts will act as the cathode. In such case, the material of this contact alone may contain the high vapor pressure constituent. For example, where a silver-cadmium contact will always serve as the cathode, the other contact may be of iron alone; or where an iron-bismuth contact will always

serve as the cathode, the other contact may be of silver alone. Another type of interrupter where only one of the contacts need contain the high vapor pressure constituent is an interrupter in which the arcing gap is so short that the anode can supply sufficient vapor pressure to hold the chopping level to an acceptable value. For this latter type of interrupter, either contact could be formed of silver-cadmium and the other of iron alone; or alternatively either contact could be formed of iron-bismuth and the other of silver alone. As another example, one of the contacts could be formed of silver-indium and the other of iron alone inasmuch as indium, a metal with a sufficiently high vapor pressure to consistently hold chopping to an acceptable level of 4 amperes, is immiscible in iron.

As was pointed out hereinabove for immiscible elements to have good seizure resistance, one other requirement in addition to immiscibility must usually be met. This requirement is that at least one metal of each possible combination of the metals of the opposing contacts should be from the B-subgroup of the periodic table. The bond between B-subgroup metals and others tends to be less metallic and hence more brittle than the bond between A-subgroup metals. This brittleness allows these bonds to be more easily broken and, hence, reduces the frictional resistance and the tendency to seize. This requirement that one of the metals of each possible pair be in the B-subgroup of the periodic table is met in the silver-cadmium, iron-bismuth contact combination by virtue of the fact that silver, cadmium, and bismuth are all B-subgroup metals. Indium, mentioned in the preceding paragraph, is also a B-subgroup metal.

Another example of a metal combination meeting the hereinabove-described requirement for immiscibility, B-subgrouping, and sufficient vapor pressure to hold the chopping level below 4 amperes is a contact pair in which one contact is formed of silver-lead and the other of iron-manganese. Another example is a contact pair in which one contact is formed of silver-bismuth and the other of iron-manganese.

In contrast to the high seizure resistance of metals satisfying the immiscibility and B-subgrouping requirement set forth above, metals that are miscible with each other ordinarily have poor resistance to seizure. Even metals that are immiscible with each other ordinarily have poor resistance to seizure if the two metals are both A-subgroup metals. The probable reason for this poor seizure resistance of miscible and A-subgroup metals is that the welded junctions formed between projections on the two sliding surfaces are stronger than the weaker of the base metals. As a result, sliding action, instead of shearing these junctions at their interface, produces a wiping or smearing action that tears particles from the base metal and soon results in seizure. If the welded junctions that are formed are brittle and weaker than the weaker base metal, then the junctions will shear at the interface and seizure resistance will be high. One additional way of imparting brittleness and weakness to such junctions is to use for the opposing contacts metals that form well-defined intermetallic compounds with each other, such as iron and antimony. The antimony, if desired, can be alloyed with silver to impart improved mechanical properties thereto. Intermetallic compounds are known to be brittle, and this brittleness imparts weakness to the junctions in question, allowing them to be more easily broken. It is assumed in this latter example that the application is one where only one of the contacts need contain a high vapor pressure metal to limit the chopping to the required level.

To free the internal surfaces of my interrupter of adsorbed gases and contaminants, it is necessary to subject the interrupter to a high temperature bake-out. A minimum temperature for such a bake-out is about 500° K. Temperatures of this order cause certain materials to vaporize to such a great extent that the insulation of the

interrupter will become detrimentally coated with metal upon subsequent condensation of the vapors. For this reason, I avoid materials having a vapor pressure greater than about 10^{-3} mm. of mercury at 500° K. Cadmium in pure form is such a material. Cadmium, may, however be alloyed with other metals such as silver to provide materials with sufficiently low vapor pressures, i.e., below 10^{-3} mm. of mercury at 500° K.

Although the above description has been devoted primarily to sliding-type contacts, certain broader aspects of the invention are also applicable to butt-type contacts. Though there is little or no sliding action present in such contact arrangements to produce contact-welding or seizure, these latter problems can arise due to such factors as contact-bounce, particularly under heavy current conditions. This contact-welding tendency can be lessened by using for the opposed butt-contacts dissimilar materials of the character set forth hereinabove in combination with magnetic means for driving high current arcs off of the contact-making surfaces to preclude an appreciable amount of metal from being transferred onto either contact-making surface from the other contact. This is illustrated more specifically in FIG. 6, where a pair of annular disc-shaped contacts 60 and 62 are shown disposed in circuit-closing engagement. Each contact is provided with an annular contact-making region 66 which butts against the annular contact-making region of the other contact when the contacts are in the closed position shown. These contact-making regions are formed of the dissimilar metals set forth hereinabove to lessen the tendency of welding to occur therebetween. Also, each contact has a central recess 67 that forces current flowing through the surfaces 66 to flow a radially-outward bowing loop-shaped path indicated by the dotted line L. The magnetic effect of current flowing through this path L is to lengthen the loop and thus drive off of these contact-making regions 66 any arcs of a high enough current content to transfer appreciable quantities of metal from one contact to the other. This protects each of the contact-making regions 66 from the accumulation of significant quantities of metal from the other contact. The magnetic effect of this loop circuit also forces metallic vapor generated from the contacts radially-outward and away from the contact-making regions 66, thus further lessening any accumulation of metal from the other contact on either of the contact-making surfaces.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A vacuum-type circuit interrupter comprising an evacuated envelope, a pair of separable sliding contacts located within said envelope and having sliding surfaces that are slidable on each other, said contacts being separable to establish circuit interrupting arcs between predetermined regions of said sliding surfaces, magnetic means for consistently forcing all arcs except light-current arcs off of said sliding surfaces and for forcing arc-generated vapors away from said sliding surfaces, said sliding surfaces being formed from dissimilar conductive materials which are immiscible in each other at solid state temperatures, the material of at least one of said sliding surfaces comprising a metal having a low thermal conductivity in comparison to copper and a vapor pressure at least as high as that of tin at temperatures exceeding 2000° K., said metal being present in quantities sufficient to consistently hold the current chopping level to no more than 4 amperes when interrupting currents of less than 50 amperes peak value, said sliding surfaces being substantially completely free of sorbed gases, all possible com-

binations of the constituents of opposed sliding surfaces including a B-subgroup metal.

2. The vacuum interrupter of claim 1 in which the material of each of said sliding surfaces comprises a high vapor pressure metal of the type defined in claim 1, the high vapor pressure metals of the two sliding surfaces being dissimilar and immiscible with each other.

3. A vacuum-type circuit interrupter comprising an envelope evacuated to a pressure lower than 10^{-4} mm. of mercury, a pair of separable sliding contacts located with said envelope and having sliding surfaces that are slidable on each other, said contacts being separable to establish circuit interrupting arcs between predetermined regions of said sliding surfaces, magnetic means for consistently forcing all arcs except light-current arcs off of said sliding surfaces and for forcing arc-generated vapors away from said sliding surfaces, said sliding surfaces being formed from dissimilar plural constituent materials, each material having a vapor pressure less than 10^{-3} mm. of mercury at 500° K. and a low chemical affinity for oxygen as compared to aluminum, magnesium, and calcium, each material including as one of its constituents a high vapor pressure metal having a vapor pressure at least as great as that of tin at temperatures exceeding 2000° K., said high vapor pressure metal being present in sufficient quantity to consistently hold the current chopping level to no more than 4 amperes when interrupting currents less than 50 amperes peak value, said high vapor pressure metal having a thermal conductivity substantially less than that of copper and silver if the metal is one having characteristic vapor pressures generally equally or lower than those of silver for given temperatures, said sliding surfaces being substantially completely free of sorbed gases, all of the constituents of one of said sliding surfaces being substantially immiscible with all of the constituents of the other of said sliding surfaces at solid state temperatures, all possible combinations of the constituents of opposed sliding surfaces including a B-subgroup metal.

4. A vacuum-type circuit interrupter comprising an envelope evacuated to a pressure lower than 10^{-4} mm. of mercury, a pair of separable sliding contacts located within said envelope and having sliding surfaces that are slidable on each other, said contacts being separable to establish circuit interrupting arcs between said sliding surfaces, magnetic means for consistently forcing all arcs except light current arcs off of said sliding surfaces and for forcing arc-generated vapors away from said sliding surfaces, said sliding surfaces being formed from dissimilar materials which are immiscible in each other at solid state temperatures, each material having a vapor pressure less than 10^{-3} mm. of mercury at 500° K. and having a low chemical affinity for oxygen as compared to aluminum, magnesium, and calcium, the material of at least one of said sliding surfaces comprising a metal having a vapor pressure at least as great as that of tin at temperatures exceeding 2000° K., said high vapor pressure metal being present in sufficient quantity to consistently hold the current-chopping level to no more than 4 amperes when interrupting currents of less than 50 amperes peak value, said high vapor pressure metal having a thermal conductivity substantially less than that of copper and silver if the metal is one having characteristic vapor pressures generally equalling or lower than those of silver for given temperatures, said sliding surfaces being substantially completely free of sorbed gases, all possible combinations of the constituents of opposed sliding surfaces including a B-subgroup metal.

5. The vacuum-type circuit interrupter of claim 4 in which the material of each of said sliding surfaces comprises a high vapor pressure metal of the type defined in claim 4, the high vapor pressure metals of the two sliding surfaces being dissimilar and immiscible with each other.

6. A vacuum-type circuit interrupter comprising an

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envelope evacuated to a pressure lower than 10^{-4} mm. of mercury, a pair of separable sliding contacts located within said envelope and having sliding surfaces that are slidable on each other, said contacts being separable to establish circuit-interrupting arcs between said sliding surfaces, magnetic means for consistently forcing all arcs except light-current arcs off of said sliding surfaces and for forcing arc-generated vapors away from said sliding surfaces, one of said sliding surfaces being formed an alloy of silver and a first high vapor pressure metal from the B-subgroup of the periodic table having a vapor pressure at least as great as that of lead, the other of said sliding surfaces being formed from an alloy of iron and a second high vapor pressure metal having a vapor pressure at least as great as that of lead, said first high vapor pressure metal being immiscible with iron and with said second high vapor pressure metal at solid state temperatures and said second high vapor pressure metals being immiscible with silver, each of said alloys having a vapor pressure less than 10^{-3} mm. of mercury at 500° K., and said predetermined region being substantially completely free of sorbed gases.

7. A vacuum-type circuit interrupter for interrupting a power circuit carrying oscillating currents having recurrent natural current zeros, comprising: an envelope evacuated to a pressure lower than 10^{-4} mm. of mercury, a pair of spaced apart terminals for connection to said power circuit, a pair of sliding contacts located within said envelope and connected in circuit with said terminals, said contacts having sliding surfaces that are slidable on each other, said contacts being separable to establish circuit interrupting arcs between said sliding surfaces, magnetic means for consistently forcing all arcs except light-current arcs off of said sliding surfaces and for forcing arc-generated vapors away from said sliding surfaces, one of said sliding surfaces being formed from an alloy of silver and cadmium, the other of said sliding surfaces being formed from an alloy of iron and bismuth, said sliding surfaces being substantially completely free of sorbed gases and contaminants.

8. A vacuum-type circuit interrupter for interrupting a power circuit carrying oscillating current having recurrent natural current zeros, comprising: an envelope evacuated to a pressure lower than 10^{-4} mm. of mercury; a pair of spaced-apart terminals for connection to said power circuit; a pair of separable sliding contacts located within said envelope and connected in circuit with said terminals; said contacts being separable to establish circuit-interrupting arcs between predetermined regions of said contacts which are slidable on each other; magnetic means for consistently forcing all arcs except light-current arcs off of the sliding surfaces of said contacts and for forcing arc-generated vapors away from said sliding surfaces, each of said sliding surfaces being formed from dissimilar materials having a sufficiently high seizure resistance against each other to prevent seizure of the sliding contacts during extensive operation of said interrupter, each material having a vapor pressure less than 10^{-3} mm. of mercury at 500° K. and having a low chemical affinity for oxygen as compared to aluminum, magnesium, and calcium; the material of at least one of said contact regions comprising a metal having a vapor pressure at least as great as that of tin at temperatures exceeding 2000° K.; said high vapor pressure metal being present in sufficient quantity to consistently hold the current chopping level to no more than 4 amperes when interrupting currents of less than 50 amperes peak value; said high vapor pressure metal having a thermal conductivity substantially less than that of copper and silver if the metal is one having characteristic vapor pressures generally equalling or lower than those of silver for given temperatures; said contact regions being substantially completely free of sorbed gases.

9. The interrupter of claim 8 in which the materials of said sliding surfaces are selected from a group consisting essentially of metals immiscible in the consti-

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tutents of the other sliding surfaces at solid state temperatures and metals forming intermetallic compounds with the constituents of the other sliding surface, at least one metal of any combination of immiscible constituents of opposite contacts being a B-subgroup metal.

10. A vacuum-type circuit interrupter comprising an evacuated envelope, first contact structure within said envelope comprising a plurality of fingers defining a socket, second contact structure within said envelope comprising a plug movable into and out of said socket, said plug having an outer peripheral surface that is slidably engaged by said fingers during movement into and out of said socket, means including a generally-annular groove in said plug for forcing current flowing through the point at which said contact structures part during an opening operation to follow a loop-shaped path that has a magnetic effect tending to drive arcs established at said point of contact-part off of the sliding surfaces of said contact structures, said groove extending longitudinally into said plug toward the inner end of said socket at least to a point longitudinally-adjacent the point of contact-part, the sliding surfaces of said contact structures being formed of materials which are substantially immiscible in each other at solid state temperatures, all possible combinations of the constituents of opposed contact regions including a B-subgroup metal, said sliding surfaces being substantially completely free of sorbed gases.

11. The vacuum-type circuit interrupter of claim 10 to which the material of the contact region immediately adjacent the point of contact-part comprises a metal having a low thermal conductivity in comparison to silver and copper and a vapor pressure at least as high as that of tin at temperatures exceeding 2000° K., said metal being present in a sufficient quantity to consistently hold the current chopping level to no more than 4 amperes when interrupting alternating currents of less than 50 amperes peak value.

12. The interrupter of claim 10 in which the sliding surface of one of said contacts is formed of a solid solution alloy of silver and cadmium, and the coating sliding surface of the other of said contacts is formed of an iron-bismuth mixture.

13. A vacuum-type circuit interrupter comprising an evacuated envelope, a pair of separable contacts located within said envelope and having contact-making regions that are engageable with each other, said contacts being separable to establish circuit interrupting arcs between said contact-making regions, magnetic means for consistently forcing all arcs except light-current arcs off of said contact-making regions and for forcing arc generated vapors away from said contact-making regions, said contact-making regions being formed from dissimilar conductive materials which are immiscible in each other at solid state temperatures, the materials of at least one of said contact-making regions comprising a metal having a low thermal conductivity in comparison to copper and a vapor pressure at least as high as that of tin at temperatures exceeding 2000° K., said metal being present in quantities sufficient to consistently hold the current chopping level to no more than 4 amperes when interrupting currents of less than 50 amperes peak value, said contact-making regions being substantially completely free of sorbed gases, all possible combinations of the constituents of opposed contact-making regions including a B-subgroup metal.

14. A vacuum-type circuit interrupter comprising an evacuated envelope, a pair of separable contacts located within said envelope and having contact-making regions that are engageable with each other, said contacts being separable to establish circuit interrupting arcs between said contact-making regions, magnetic means for consistently forcing all arcs except light-current arcs off of said contact-making regions and for forcing arc generated vapors away from said contact-making regions, said contact-making regions being formed from dissimilar conductive materials selected from a group consisting essen-

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tially of metals immiscible in the constituents of the other contact-making region at solid state temperatures and metals forming inter-metallic compounds with the constituents of the other contact-making region, at least one metal of any combination of immiscible constituents of opposed contacts being a B-subgroup metal.

15. The vacuum-type circuit interrupter of claim 14 in which said contacts are sliding contacts and said contact-making regions are surfaces that slidably engage each other.

16. A vacuum-type circuit interrupter comprising an envelope evacuated to a pressure lower than 10^{-4} mm. of mercury, a pair of separable contacts located within said envelope and having contact-making regions that are engageable with each other, said contacts being separable to establish circuit interrupting arcs between said contact-making regions, magnetic means for consistently forcing all arcs except light-current arcs off of said con-

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tact-making regions and for forcing arc-generated vapors away from said contact-making regions, one of said contact-making regions being formed an alloy of silver and a first high vapor pressure metal from the B-subgroup of the periodic table having a vapor pressure at least as great as that of lead, the other of said contact-making regions being formed from an alloy of iron and a second high vapor pressure metal having a vapor pressure at least as great as that of lead, said first high vapor pressure metal being immiscible with iron and with said second high vapor pressure metal at solid state temperatures and said second high vapor pressure metals being immiscible with silver, each of said alloys having a vapor pressure less than 10^{-3} mm. of mercury at 500° K. and said contact-making regions being substantially completely free of sorbed gases.

No references cited.