

Aug. 26, 1930.

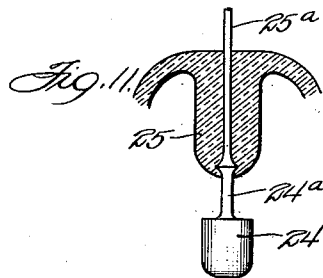
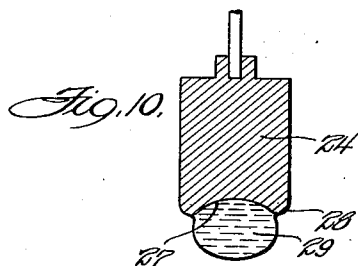
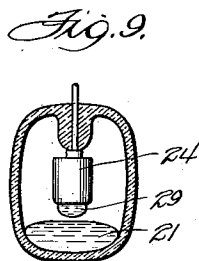
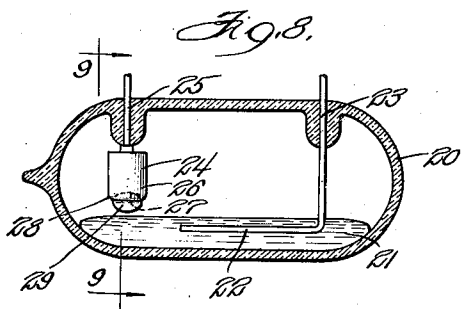
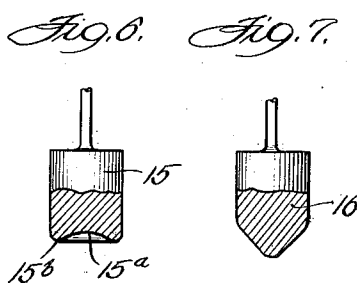
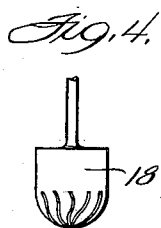
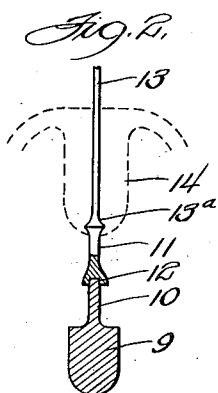
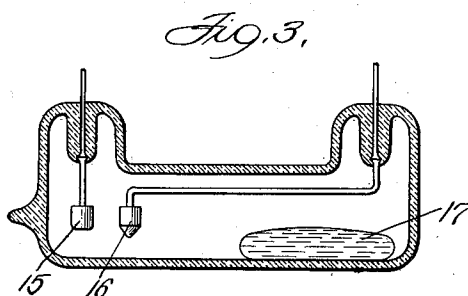
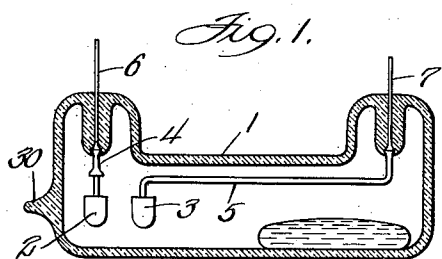
L. A. M. PHELAN

1,774,108

ELECTRIC SWITCH

Filed March 31, 1926

2 Sheets-Sheet 1



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Aug. 26, 1930.

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1,774,108

ELECTRIC SWITCH

Filed March 31, 1926

2 Sheets-Sheet 2

Fig. 12.

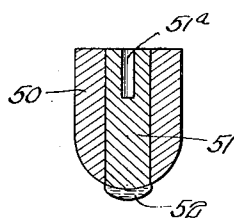


Fig. 14.

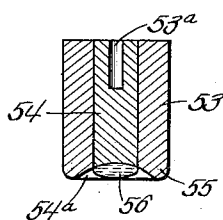


Fig. 16.

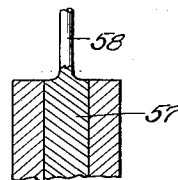


Fig. 13.

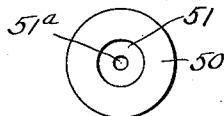


Fig. 15.

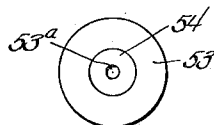


Fig. 17.

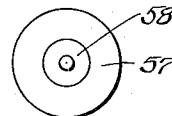


Fig. 18.

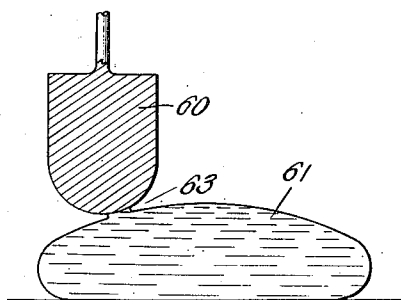
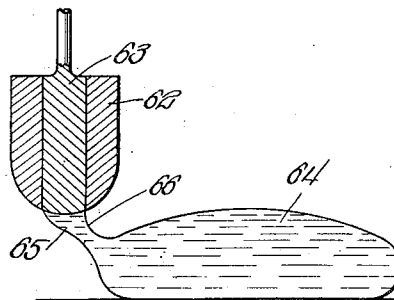


Fig. 19.



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UNITED STATES PATENT OFFICE

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OF MARYLAND

ELECTRIC SWITCH

Application filed March 31, 1926. Serial No. 98,665.

My invention relates to electric switches and it has special reference to improvements in electric contactors wherein the conducting terminals or electrodes at which the electrical
5 contact making-and-breaking arcs occur are enclosed in a sealed container which has been evacuated and refilled with an inert gas and also contains a compact body of current conducting fluid, such as mercury, through the
10 medium of which the electrodes are brought into electrical conducting relation to one another.

My present invention refers particularly to electrical contactors of the character indicated above which are adapted for commercial
15 operations and to meet the requisite service conditions as to current carrying capacity, voltage, life, reliability, etc., as render them suitable for commercial installations.

20 One object of my present invention is to provide an electric switch, as referred to above, which is capable of opening and closing an electric circuit an extraordinarily large number of times without undergoing
25 substantial deterioration or disintegration when operating under service conditions, such as current and voltage requirements, dependability and life that are required of commercial electrical apparatus.

30 Another object of my invention is to provide an electric contactor which is capable of being operated with a minimum expenditure of energy and on electric circuits handling substantial quantities of current.

35 Another object of my present invention is to provide an electric switch of the contactor type which comprises a movable body of mercury that is rendered highly mobile or active or "frisky" in order that the electric circuit
40 opening and closing functions may be performed with the expenditure of a very small amount of energy.

One form of contactor that conforms to the foregoing object of my invention comprises
45 a tiltable contactor in which the body of mercury is rendered highly active or mobile or "frisky" in order that movement of the body of mercury into contact making-and-breaking relations with respect to the electrodes
50 may be effected by tilting the contactor

through a very small angular displacement.

Another object of my invention is to provide electric contactors of the type indicated above in which the electrodes are made of
55 materials rendering them substantially non-disintegrating and non-deteriorating under the current conditions to which the contactors may be subjected in commercial installations.

A further object of my invention is to provide an electrical contactor switch in which
60 the electrodes are made of different materials in order to control the movement of the body of conducting liquid, such as the mercury, under certain predetermined conditions.

A further object of my invention is to provide a process for treating mercury that renders it highly desirable for use in contactors of the character referred to. By
65 means of my process, as herein described, mercury is capable of being made into a highly mobile, flowable mass which may be aptly characterized by the word "frisky." The process of my invention whereby mercury
70 is treated permits of the treated mercury being used effectively in contactors wherein the mercury may flow from one end to the other end of the container thereby performing the circuit making-and-breaking
75 functions of the contactor while tilting the contactor through a very small angular displacement.

Another object of my present invention is to provide a new process for treating contactors whereby the electrodes thereof at
85 which the electric arcs are made and broken are wetted or covered with a film of mercury whereby these electrodes are adapted to handle large quantities of electric current without undergoing substantial deterioration or
90 disintegration.

Another object of my invention is to provide an electric contactor comprising a body of mercury in which the electrodes are so
95 constructed and the materials comprising the electrodes are so selected that the contactor is capable of handling large quantities of current without undergoing any substantial deterioration or disintegration.

Other objects and features of novelty of 100

my present invention will appear hereinafter and for a better understanding of the nature, scope and characteristic features of my present invention, reference may now be had to the following description and the accompanying drawings, in which—

Figure 1 is a view, partially in elevation and partially in section, of a contactor embodying a form of my invention in which the electrodes are disposed in one end of the container;

Fig. 2 is a view, partially in elevation and partially in section, showing the details of construction of an improved electrode, its supporting member and a leading-in wire;

Fig. 3 is a view, partially in elevation and partially in section, of a modified form of contactor embodying my invention;

Fig. 4 is a view in elevation of an electrode that may be incorporated in contactor switches of my present invention;

Fig. 5 is a plan view of the electrode illustrated in Fig. 4;

Fig. 6 is a view, partially in section, of one of the electrodes comprised in the contactor of Fig. 3;

Fig. 7 is a cross-sectional view of another one of the electrodes comprised in the contactor of Fig. 3;

Fig. 8 is a view, partially in elevation and partially in section, of a contactor switch embodying another form of my invention;

Fig. 9 is a view taken along the line 9—9 of Fig. 8;

Fig. 10 is an enlarged cross-sectional view of the electrode of Fig. 9, showing a drop of mercury adhering to the under surface of the electrode;

Fig. 11 is a view similar to Fig. 2, showing a modified form of construction for an electrode of a contactor;

Fig. 12 is a cross-sectional view of a modified form of an electrode embodying my invention which is made up of a plurality of different materials, this electrode being shown as having a substantially hemispherical lower end;

Fig. 13 is a plan view of the electrode of Fig. 12;

Fig. 14 is a cross sectional view showing a modified form of electrode wherein the lower end is provided with a concavity or recessed portion;

Fig. 15 is a plan view of the electrode illustrated in Fig. 14;

Fig. 16 is a cross-sectional view showing a modified form of electrode construction which may be incorporated in the electrodes of Figs. 12 and 14;

Fig. 17 is a plan view of the electrode of Fig. 16;

Fig. 18 is a diagrammatic view to illustrate the method in which a body of mercury in a contactor breaks at an electrode having a rounded lower end, as shown; and

Fig. 19 is another diagrammatic view to illustrate the method in which a body of mercury in a contactor may break from an electrode which is provided with a core made of a material to which the mercury adheres with some tenacity.

Referring to the structure shown in Fig. 1 the contactor comprises a container 1, such as a glass tube, that is hermetically sealed. The electrodes 2 and 3, which are of a substantial and concentrated mass, constitute enlarged heads upon supporting members 4 and 5 respectively. The supporting members 4 and 5 are, in turn, connected to leading-in wires 6 and 7 respectively, made of a material, such as dumet or nitram, that ensures a permanent hermetical seal with the glass walls of the container 1. A body of mercury 8 is also disposed within the container 1 and serves to bridge the electrodes 2 and 3 and thereby to establish an electric circuit through the contactor. The contactor is of the tiltable type and, consequently, the body of mercury 8 moves over the bottom surface of the container 1 in order to open and close the electric circuit between the electrodes 2 and 3 when the contactor is tilted. The container 1 is evacuated of atmospheric air and filled with an inert gas, such as hydrogen, preferably substantially at atmospheric pressure.

The leading-in wires 6 and 7 are capable of handling commercial quantities of electric current and are preferably made of a suitable wire in order to ensure the retention of permanent hermetic seals for the container 1 when the seals become heated or when substantially high currents are handled by the contactor. A common form of a sealing-in wire for ordinary glass is known in the trade as "Dumet" but there are other alloys that may serve as proper sealing-in wires under certain conditions, such as the alloy known in the trade as "nitram". If the glass container 1 is made of pyrex glass or a boro-silicate glass, the leading-in wires 6 and 7 may be made of tungsten which has been found very satisfactory as a sealing-in wire for pyrex glass and the like. The supporting members 4 and 5 for the electrodes are preferably made of a non-deteriorating or inert material, such as iron. These supporting members 4 and 5 are connected to their respective leading-in wires 6 and 7 by means of welding or by any other satisfactory means, but the leading-in wires 6 and 7, if made of Dumet or other deteriorating materials, are precluded from being exposed within the interior of the container 1 by means of the glass shanks forming the seals. However, if the leading-in wires 6 and 7 are made of materials that do not of themselves deteriorate or cause deterioration of the contactor they may be exposed within the container.

The exposed supporting members 4 and 5, however, are made of a non-deteriorating

material and I have found iron to be quite satisfactory. The electrodes 2 and 3 in this instance are made of an iron-chromium alloy and I have found that such an alloy containing approximately 18% of chromium is very satisfactory for this purpose. The lower portions of the electrodes 2 and 3 are preferably rounded to form hemispherical ends with which the body of mercury 8 comes in contact. Moreover, the electrodes 2 and 3 are preferably highly polished in order substantially to eliminate irregularities on their exposed surfaces which would tend to cause disintegration of the electrodes when substantial quantities of current are handled by the contactor. The electrodes 2 and 3 are welded or secured to their respective supporting members 4 and 5 in any suitable fashion.

The metals exposed to the interior of the container 1 are substantially permanently non-deteriorating and non-disintegrating under the conditions obtaining within the container. The atmospheric air is evacuated from the container 1 to a substantially high degree and the container is then filled with an inert gas, such as hydrogen, to a pressure preferably approximating atmospheric pressure. It is not essential that the pressure of the gas within the container be atmospheric but it is desirable that the pressure of the gas be as high as practicable in order that the electric arcs obtaining within the contactor, as the electric circuit is made and broken, will be readily quenched. The body of mercury 8 is of a high degree of purity except in those instances where I desire to employ active or highly mobile or frisky mercury. By properly selecting all of the materials exposed within the interior of the container 1 I greatly minimize the deterioration and the disintegration of the contactor when it is subjected to severe service conditions. I have found that hydrogen gas is permanently inert to the materials entering into the construction of the contactor of Fig. 1.

I have found that by making the electrodes 2 and 3 of an iron chromium alloy that I am able substantially to eliminate any disintegration of the electrodes. The mercury does not amalgamate to any appreciable degree with iron chromium alloys of which the electrodes 2 and 3 are formed. By making the lower ends of the electrodes 2 and 3 hemispherical in shape and polishing the electrodes 2 and 3 which take a high polish, I have been able to procure a highly satisfactory contactor which will handle substantial quantities of electric current for a great number of times without affecting its operating efficiency.

While I have mentioned that the electrodes 2 and 3 may be made of the shape shown in Fig. 1, it is conceivable that elec-

trodes of other shapes may be employed. Also, it is not essential that the electrodes 2 and 3 be provided with polished surfaces, but this is highly desirable. While I have secured satisfactory results by using an iron-chromium alloy comprising approximately 18% chromium, it is to be understood that I do not limit my invention to this specific iron-chromium alloy, but that my invention comprehends the use of all iron-chromium alloys that will serve satisfactorily in a contactor.

In Fig. 2 I have shown a modified form of electrode construction. The electrode may be made of any suitable material, preferably an iron-chromium alloy or iron alone, and comprises a main body portion 9 having integrally formed therewith at its upper portion a shank or extension 10. A support 11 which, as hereinbefore described, is made of a non-deteriorating and non-disintegrating metal, such as iron, is welded to the upper end of the shank 10 as shown at 12. The leading-in conductor 13, which may be made of dumet or any other satisfactory sealing-in material, is shown as being welded at 13^a to the support 11. If the sealing-in wire 13 is made of dumet the electrode assembly, when incorporated in a glass container, is such that the glass seal, as shown by the dotted lines 14, completely embeds the lower portion of the sealing-in wire 13 thereby precluding it from being exposed within the interior of the container, since copper and some other metals which dumet comprises readily amalgamates with mercury thereby causing deterioration of the contactor.

While I have herein referred to the electrodes 2 and 3 as being made of chromium iron, the alloy is also known in the art under other names, as chromium steel.

Referring to Fig. 3, the contactor herein illustrated may be of a construction similar to that shown and described in Fig. 1, except that the electrodes 15 and 16 are different. This contactor of Fig. 3 is adapted to operate on a wide operating angle; that is, the electric circuit is to be made and broken by tilting the contactor through an angular displacement approximating 4° to 8° from the horizontal. The electrode 15 which is shown in section in Fig. 6, is provided with a lower recessed or concave surface 15^a, the concavity of which is sufficient to retain therein a globule or drop of mercury or at least a substantially heavy film of mercury on its active surface. The periphery 15^b of the electrode 15 is rounded in order to eliminate all sharp edges thereby precluding the electric arcs from pitting the electrode 15.

In the specific embodiment shown in Fig. 3, the electrode 15 may be made of nickel or any other metal that amalgamates with mercury to a substantially higher degree than that which obtains with respect to the co-

operating electrode 16. I have found that substantially pure nickel causes mercury to adhere to it with some tenacity and, consequently, the contactor will have to be tilted through an angle of about 4° to 8° in order to cause the body of mercury 17 to break contact with the electrode 15. I have found nickel to be a very satisfactory material from which to make the electrode 15. The purpose of the electrode 15 is to create an adhering action or cause adhesion to be established therebetween and the body of mercury 17 which is snapped or broken with rapidity when the contactor is tilted through a sufficiently wide angle. This causes the mercury to make a quick break from the electrode 15.

The electrode 16, which is shown in cross-section in Fig. 7, is provided with a conical pointed lower end and is preferably made of a material which does not become readily wetted by the mercury or appreciably amalgamate therewith; that is, the mercury does not adhere to the electrode 16 with any degree of tenacity. I have found that a very satisfactory contactor may be made if the electrode 16 is made of an iron-chromium alloy of the character described in connection with the electrodes 2 and 3 of Fig. 1, but the electrode 16 may be made either of pure iron or tungsten or molybdenum, it being understood, however, that the electrode 16 is of such construction and is made of such material that the body of mercury 17 will not adhere strongly to it and of such shape that the mercury will not be obstructed in its rapid flow to and away from the electrode 15. The pointed end of the electrode assists in accomplishing this end.

The concavity of the electrode 15 ensures that a satisfactory quantity of mercury will be retained on the lower end of the electrode thereby providing in effect a mercury-to-mercury make-and-break, while the pointed end of the electrode 16 and the material of which it is made will substantially preclude mercury from adhering thereto. The switch shown in Fig. 3 is adapted to handle substantial quantities of electric current and, as hereinbefore described, serves to make a quick break in the electric circuit when the contactor is tilted through a proper angle.

Other electrodes may be substituted for the electrode 15, such as an electrode 18 shown in Figs. 4 and 5. Here the lower rounded end of the electrode 18 is roughened or scolloped in any suitable manner, such as that shown in the plan view of Fig. 5. When an electrode 18, such as that shown in Figs. 4 and 5, is substituted for the electrode 15 in the contactor of Fig. 3, the making and breaking of the electric circuit through the medium of the body of mercury 17 is not greatly dependent upon the tilting angle of the contactor. In other words, the point of opening

and closing the circuit through the contactor is not greatly dependent upon its angular displacement. For instance, the circuit through the contactor of Fig. 3, when the electrode of Figs. 4 and 5 is substituted for the electrode 15, may be made and broken whether the contactor is tilted through an angle, for example, of substantially two degrees or through an angle or displacement of substantially from 4 to 5 degrees. When the electrode 18 is incorporated in a contactor, the electrode 18 is preferably made of a material which slightly amalgamates with mercury or which becomes "wetted" by the mercury, such as I have hereinbefore described. On tilting the contactor, the body of mercury 17 will adhere to the electrode 18 until the proper angular displacement of the contactor is effected and then the body of mercury 17 will snap away from the electrode 18 and be offered very little resistance in this path of flow by the electrode 16. I have found that, in constructing a contactor as shown in Fig. 3 in which an electrode of the general type of Figs. 4 and 5 is substituted for the electrode 15, the making and breaking of the electric circuit is not greatly affected by the tilting angle, within certain limits, through which the contactor is moved.

Referring again to the construction shown in Fig. 1, I have heretofore described electrodes 2 and 3 as being made preferably of an iron chromium alloy or of so-called chromium steel. I have also stated that I have found an iron chromium alloy comprising substantially 18% chromium as being a very satisfactory material for constructing the electrodes 2 and 3. Electrodes made of this material disintegrate at a very low rate even though the electric arcs directly impinge on them. Such electrodes also take on a high polish because of the density and the close grain of iron-chromium alloys and, therefore, minute protuberances and the like do not extend from the body of the electrodes which would cause the electrodes to disintegrate under the action of the electric arcs impinging thereupon.

Under certain conditions it may be desirable to vary the construction of the contactor illustrated in Fig. 1 by making the electrode 2 of a metal which readily wets with mercury or amalgamates with the mercury to such an extent that the body of mercury 8 will adhere to the modified electrode 2 until the contactor is tilted through a predetermined angle. In this circumstance, the electrode 2 may be made of nickel or some other suitable material that mercury adheres to with sufficient tenacity to preclude the receding therefrom of the body of mercury 8 until the contactor has been tilted through the desired angle. Or the electrode 2 may be replaced by an electrode such as that of Figs. 4 and 5 or by an electrode such as the electrode 15 of Fig. 3.

3. The electrode 3 may, in this instance, be made of a metal that does not readily become wetted with the mercury or does not amalgamate with the mercury. In this circumstance, the electrode 3 may be made of molybdenum or iron or tungsten or iron-chromium alloy. The purpose of making the electrode 3 of these non-amalgamating materials is to minimize any resistance that the electrode 3 may offer to the flow of the body of mercury 8 as it advances to and recedes from the electrode 2. In this manner, the contactor may serve as a quick breaking electric switch as described in connection with the contactor of Fig. 3.

In Fig. 8 I have illustrated a contactor that is adapted to handle substantially large currents. The container 20 may be made of glass of the character employed in the manufacture of incandescent lamps or it may be made of a boro silicate glass or any of the so-called high temperature glasses. The container 20 may have an elongated shape as shown in Fig. 8 and a cross-sectional form as shown in Fig. 9. The body of mercury 21 fills the lower portion of the container 20 and completely immerses the horizontal portion of an electrode 22 that is hermetically sealed in the glass container at 23. The electrode 22 may be made of tungsten which ensures the making of a substantially permanent hermetical seal when the container 20 is made of a boro silicate glass. A second electrode 24 is sealed in the container at 25. The electrode 24 may be made of iron or of an iron chromium alloy. The container 20 is evacuated of atmospheric air and preferably filled with hydrogen gas at atmospheric pressure.

As shown by the dotted line 26 and by the view of Fig. 10, the electrode 24 is provided with a concave or cup-shaped lower end 27, the periphery of which is rounded off as shown at 28. The body of mercury 21 in contacting with the electrode 24 when the contactor is tilted to circuit closing position will affect the electrode 24 after a few makes and breaks of heavy electric current so that thereafter the electrode 24 will retain in its cavity 27 a drop of mercury 29 which will adhere to the lower end of the electrode somewhat in the manner shown in Fig. 10 except that the showing of Fig. 10 is exaggerated. Thereafter, the making and breaking of the electric circuit will occur between the drop of mercury 29, adhering to the lower end of the electrode 24, and the body of mercury 21. The mass of the body of mercury 21 and the mass of the electrode 24 must be sufficient to prevent the body of mercury 21 from tenaciously clinging to the electrode 24 when the contactor is tilted through its operating angle or to its circuit opening position. When the electrode 24 becomes hot, as occurs when the contactor is in operation for a sufficient pe-

riod of time, the repelling action between the electrode 24, if made of iron or an iron chromium alloy, will prevent the body of mercury 21 from tenaciously clinging thereto except for the globule of mercury 29. The concavity 27 formed in the lower end of the electrode 24 is preferably of such shape that the drop of mercury 29 adhering thereto will assume at its lower portion a hemi-spherical shape. It will be noted that the contactor of Figs. 8, 9 and 10, after the globule of mercury 29 is formed on the electrode 24, constitutes an electric switch in which the breaking and making of the electric circuit is effected between the body of mercury 21 and the adhering globule of mercury 29.

If the container 20 is made of lead glass the seal 23 may be made and constructed as shown in Fig. 2, namely, the leading-in wire may be made of Dumet and, at the point just before it emerges from the glass, the Dumet lead may be affixed to an inert wire, such as iron, that may be extended to form the electrode 22. It is desirable that none of the Dumet lead be exposed within the interior of the container so that it will come into contact with the body of mercury 21. The seal 25 may be similarly constructed or constructed as shown in Fig. 11 wherein the Dumet leading-in wire 25^a is completely embedded in the glass so as to preclude its exposure within the container. The electrode 24 is shown in Fig. 11 as having an integrally formed shank 24^a which is welded to the Dumet lead 25^a at a point embedded by the glass.

I have heretofore described the body of mercury 8 of Fig. 1 as being made up of substantially pure mercury. Under many circumstances this is desirable. However, in the event that a contactor is desired which will operate to open and close a circuit by tilting the contactor through a very small angle, the mobility of the body of mercury 8 may be greatly increased in order to enhance its flowability and, to this end, I have invented a new contactor incorporating therein a highly mobile or frisky body of mercury, as well as a process for treating mercury in such a manner that it is rendered highly mobile without affecting its electrical conducting properties or causing its deterioration or disintegration when embodied in a contactor. I will explain this treatment of mercury in connection with the contactor shown in Fig. 1, but it will be readily perceived, of course, that mercury of this character may be embodied in any electric contactor, as well as be employed for other uses.

In order to increase the mobility of the mercury thereby rendering it "frisky", so as to cause it to flow back and forth rapidly in the container by tilting the container through a very slight angular displacement, I take the container prior to its being filled with the body of mercury 8 and also prior to its being

evacuated and sealed off at 30 and place therein a small quantity of a solution of hydrocyanic acid which is generally known by its formula as HCN. I then place in the container a quantity of mercury 8 sufficient to form a proper meniscus that will suffice to bridge the electrodes 2 and 3. I then shake the container in order to coat the entire inner walls thereof with the hydrocyanic acid solution and to mix therewith the mercury. The container is then evacuated in the usual manner, during which time high frequency and high tension current may be passed, if desired, between the electrodes 2 and 3. The purpose of passing this current between the electrodes 2 and 3 is to ensure the substantial elimination therefrom of occluded gases. During the time that the contactor is being thus treated by applying the high frequency and high tension current, the container is being evacuated to ensure that substantially all of the occluded gases within the electrodes 2 and 3 will be withdrawn therefrom. The evacuation of the container 1 is continued up to the neighborhood of 5 microns. This procedure is not essential but is desirable to produce a high grade contactor.

In some instances, however, I have used commercial hydrocyanic acid without dilution by inserting a small quantity only in a container by means of a medicine dropper or pipette. In other instances I have employed a one-half of one per cent solution of hydrocyanic acid, the remainder of the solution constituting distilled water. In a container of the usual size, namely about 2" long and $\frac{5}{8}$ " in diameter, I have placed from 5 to 10 drops of the aforesaid one-half of one per cent solution of hydrocyanic acid. In the event that I use a more concentrated solution of hydrocyanic acid, such as a two per cent solution, I may employ about one drop. The requisite amount of mercury is placed in the container just before or just after the admission of the hydrocyanic acid solution, and the container is then immediately shaken, agitated and evacuated while being subjected preferably to the high tension and high frequency current.

After the container has been evacuated as described above it may then be filled with hydrogen gas in order to wash the interior thereof, and, consequently, evacuated again and refilled with hydrogen gas at a pressure approximating atmospheric pressure. It is not essential, of course, that the container be washed with hydrogen gas as hereinbefore explained, but this washing of the container with hydrogen gas greatly increases the efficiency of the contactor. The contactor is then sealed off and flashed by passing current between the electrodes 2 and 3 a number of times. I have found that the flashing of the contactor, after having been filled with hydrogen gas and sealed off, with a current of

approximately 8 amperes for 100 to 200 times produces a highly efficient contactor.

While I am not able to explain the chemical action, if such occurs between the mercury and the hydrocyanic acid, either in strong or weak solution, the result that I obtain by employing the foregoing process resides in the production of a highly mobile meniscus of mercury which flows easily on the interior surfaces of the container. This readily flowable mercury may be designated as being "frisky", inasmuch as it is particularly agile and highly active. The electrical properties of the mercury are not noticeably affected and the efficiency and life of the contactor is apparently not decreased. The mercury body itself still coheres to form a readily flowable meniscus and does not readily break up into separate parts or bodies when the contactor is tilted. It appears that the hydrocyanic acid serves in the nature of a lubricant for the mercury whereby the particles comprising the meniscus of mercury assume high activity within the mass of mercury and yet cohere together to form a readily flowable meniscus which will not adhere to the glass wall of the container but flow over it apparently with less resistance than mercury not so treated. Instead of using hydrocyanic acid, as explained above, I may use other compounds of cyanide such as mercuric cyanide in solution. It is desirable of course to remove the water from the contactor, when it has been treated with these cyanide solutions. Of course, hydrocyanic acid and cyanide substances must be employed that do not cause appreciable deterioration of the contactor. The substances herein named are such materials.

While I am unable to explain the physical or chemical change, if such occurs, that the mercury partakes of when treated as hereinbefore described, the mercury particles comprising the meniscus seem to be highly lubricated which lubricating property the meniscus partakes of rendering it readily flowable over the surface of the container. Contactors treated as hereinbefore described do not show any noticeable deterioration and it is, therefore, apparent that the materials with which the mercury meniscus is lubricated do not react deleteriously with the other materials entering into the construction of the contactor. The meniscus of mercury when treated with cyanide substances partakes of a highly active character which I designate as being "frisky". The meniscus readily flows over the surface of the contactor and it appears to be highly stable in that it does not readily separate into globules but coheres to form a unitary mass. The net results of the action of the mercury appears to be that by means of my invention the meniscus of mercury is lubricated to the extent that the mercury particles are severally lubricated and the meniscus is likewise lubricated rendering the same readily flow-

able as well as highly active. The materials with which I treat the mercury to make it "frisky" also lubricate the glass wall of the container by coating the glass.

5 By utilizing the foregoing process of treating the mercury incorporated in a contactor in which hydrocyanic acid or other compounds of hydrocyanic acid or cyanide are utilized to render the mercury frisky or highly active and employing a mechanical construction for the contactor as shown in Fig. 1, I have been able to produce a highly efficient contactor that will open and close an electric circuit by tilting the contactor through an angle not in excess of two degrees from the horizontal. It is, therefore, obvious that thus I have been able to produce a contactor that will operate on commercial electric circuits by tilting the contactor through a very small angle. It will readily be seen that by providing a contactor of this character, electric switching operations may be effected at the expense of very little energy.

10 In further processing contactors in accordance with my present invention, a contactor which has been sealed off is connected to a direct current electric circuit, the positive side of the circuit being connected to that electrode which is immediately adjacent to the end of the container, namely, the electrode at which the circuit is broken, and the other electrode is connected to the negative side of the electric circuit. The contactor is then tilted through an angle to permit of a gap between the body of mercury and the electrode connected to the positive side of the circuit. The meniscus of mercury is in mechanical and electrical contact with the electrode connected to the negative side of the circuit and thereafter assumes a negative potential. On closing the exterior electric circuit an electric arc is established between the positively charged electrode and the body of mercury and the positively charged electrode, after a few minutes, will become covered with a thin deposit of mercury or, in other words, the positively charged electrode wets with the mercury while the negatively charged electrode partakes of a bright and lustrous condition. I am not able to explain the electrical and physical reactions that occur while subjecting a contactor to the foregoing treatment, but it appears that the negatively charged particles of mercury are deposited upon the positively charged electrode. This action appears to be somewhat similar to the thermionic action that occurs in a vacuum tube in which the negatively charged ions are attracted from the heated filament and deposited upon the plate electrode. I have procured very satisfactory results in processing contactors as described above when flashing the contactors under a load of 600 watters, 110 volts, for about two minutes.

65 While I have shown and described in Fig.

1, a contactor containing a "frisky" body of mercury, as hereinbefore described, it is, of course, apparent that contactors, such as shown and described in connection with the other figures of this application, may likewise be treated with hydrocyanic acid or other substances in order to lubricate the mercury comprised in them. I have constructed contactors employing mercury treated with hydrocyanic acid and other lubricants imparting similar properties to the mercury which comprise electrodes of iron, as well as electrodes made of chromium alloys, such as chromium iron or chromium steel, besides electrodes of tungsten, molybdenum, etc. I have found that hydrocyanic acid, cyanide substances or other lubricants for the mercury, as employed by me, do not affect the efficiency of the contactors while, at the same time, highly advantageous results are secured by reason of the increased degree of the mobility of the mercury. In employing the aforesaid lubricants and the process, as hereinbefore described, I am able to construct contactors embodying a minimum length of container and a minimum angular displacement, for instance between 1° and 2° from the horizontal, for opening and closing the associated electric circuit. The high mobility and lubrication of the mercury also causes a minimum adherence of the mercury meniscus to the electrodes with which it contacts and recedes from during the circuit closing and circuit opening functions. The hydrocyanic acid and the other lubricants appear to cause the mercury meniscus to have a repelling action with respect to the electrodes and all other surfaces which the mercury meniscus may contact with. It appears that the molecular structure of the mercury is modified although, as I have hereinbefore stated, I have no exact knowledge of the action which occurs by employing hydrocyanic acid, cyanide substances and other lubricants imparting similar properties to the mercury. These lubricants may cause either a chemical or a physical change in the body of the mercury but it does result in producing a highly active and "frisky" meniscus of mercury rendering it a great improvement, for many uses, over the so-called chemically pure mercury heretofore employed.

While I have found hydrocyanic acid and mercuric cyanide as the most satisfactory substances for lubricating the mercury meniscus in situ and for imparting the hereinbefore described desirable characteristics to a contactor, I have also found that muriatic acid similarly employed may be desirable under certain conditions.

In Figs 12 and 13 I have shown a modified form of electrode, the body portion 50 of which may be made of iron or an iron-chromium alloy, as hereinbefore described. A central core 51 made of nickel or other

suitable metal as will be explained later is inserted in the body portion 50. The body portion 50 is preferably made of a metal such as an iron-chromium or chromium steel alloy which does not disintegrate or deteriorate rapidly when subjected to an electric arc. This portion may also be made of tungsten, molybdenum and the like. When the body portion 50 is made of the materials mentioned above it does not readily amalgamate with or become wetted by the mercury and, therefore, only a small film, if any, of mercury adheres to the body portion 50. The core 51, which is preferably made of nickel, constitutes a material that more readily amalgamates or wets with the mercury than tungsten, molybdenum, and the like so that when the meniscus of mercury recedes from the electrode a small drop or body 52 of mercury will adhere to the core portion 51. This body of mercury 52 may be only a film of mercury but this film 52 adheres tenaciously to the core 51 probably because of the amalgamation therewith and the mercury. This ensures that in subsequent breaks between the electrode and the meniscus of mercury the breaks in the electric current or the arcs will occur between the main body of mercury in the contactor and the film 52 which adheres to the electrode core 51.

In Fig. 14 the lower portion of the electrode is provided with a recess 54^a similar to that of the electrodes described in connection with Fig. 6. In the electrode of Figs. 14 and 15 the main body portion 53 may preferably be made of an iron chromium alloy or of the materials mentioned above, and the core 54 may be preferably made of nickel or other metals that mercury will more readily adhere to. The lower portion of the electrode is rounded off as shown at 55 in order to prevent the formation of any sharp corners or edges which would tend to deteriorate and disintegrate in the event that the electric arcs occurred adjacent to them. A body or film of mercury 56 will adhere to the core 54 for the same reason that the film of mercury 52 adheres to the core 51 of the electrode illustrated in Figs. 12 and 13. The concavity or recessed portion 54^a of the electrode 53 tends to cause the body or film of mercury 56 to adhere with a high degree of tenacity to the core 54.

In both of the electrodes of Figs. 12 and 14 the leads may be inserted in openings 51^a and 53^a respectively. In Figs. 16 and 17 an electrode containing a core 57 is shown, the core 57 being provided with an extension 58 which is integrally formed therewith. This extension 58 is useful for the same purpose as the extensions formed on the electrodes illustrated in Fig. 2.

Referring again to the action of the body or meniscus of mercury with respect to the

electrodes at which the electric arcs are broken when the contactor is moved to open circuit position, reference may be had to Fig. 18 wherein an electrode 60 having a rounded lower end is shown in contact with a meniscus of mercury 61 being shown as receding from the electrode 60 just prior to the breaking of the circuit. If the electrode 60 is made of iron or an iron chromium alloy the mercury film formed thereupon is insufficient to cause any substantial or effective portion of the mercury body 61 to adhere thereto in opposition to the cohering force which exists in situ in the mass of the meniscus of mercury 61. As the circuit is being broken a very small thread of mercury 63 connects the main body of mercury 61 to the electrode 60 and when this thread 63 breaks the direct and intimate contact between the electrode 60 and the mercury 61 an arc will occur at the surface of the electrode 60 and, if the arc persists for any period of time, it may cause disintegration of the electrode. Again, if these arcs occur a great number of times, the electrode 60 may also disintegrate. Moreover, the body of mercury 61, after breaking the thread 63 and disconnecting itself completely from the electrode 60, may not possess a sufficient momentum to ensure that at all times the mercury meniscus will flow rapidly away from the electrode 60.

Now, referring to Fig. 19, the electrode 62 is shown as being provided with a core 63, similar to the electrode of Figs. 12 and 13. As the body of mercury 64 flows away from the electrode a substantial portion of mercury, indicated at 65, will adhere tenaciously to the bottom of the core 63. The mercury will be stretched as indicated at 66 to a narrower cross sectional area at a substantial distance from the electrode 62. The force of adherence between the core 63 and the body of mercury 65 is sufficient to cause the body of mercury 64, on receding further from the electrode 62, to break in the neighborhood of the narrow cross sectional portion 66. The meniscus of mercury 64 will then flow rapidly away from the electrode 62 after this rupture occurs. In this manner the arc occurs between two bodies of mercury and not at the surface of the electrode 62. The electrode is thus protected from disintegration that otherwise would occur from electric arcs occurring in intimate contact therewith.

From the foregoing, the advantages possessed of the electrodes illustrated in Figs. 12 and 14 will be apparent since a substantial film of mercury will adhere to the electrode 62 by reason of the core portion 63 and on subsequent breaks of the arc the breaks will occur between two mercury bodies, namely the body of mercury adhering to the electrode and the main body of mercury 64. In this manner the electrodes constructed in ac-

cordance with the electrode of Fig. 19 are substantially non-disintegrating and non-deteriorating since the electric breaks and makes occur between two mercury bodies which are highly satisfactory electrical contact making mediums. It is to be understood, of course, that this action occurs whether or not the body of mercury contained in the contactor has been previously treated to lubricate it in situ, as hereinbefore described. The action which I have described in connection with the diagram of Fig. 19 is effective either when untreated mercury is used or when "frisky" mercury is used.

While I have shown and described several embodiments of my invention, it is to be understood that I am not to be limited to the specific disclosures herein made, inasmuch as my invention is adaptable to wide uses and applications and I desire, therefore, that only such limitations be placed upon my invention as are set forth in the appended claims.

I claim:

1. An electrical contactor comprising an electrode of a chromium iron alloy, and a cooperating electrode made of a metal that more readily amalgamates with mercury.

2. An electrical contactor comprising an electrode of a chromium iron alloy, and a cooperating electrode made of a metal to which a mercury film readily adheres.

3. An electrical contactor comprising spaced cooperating electrodes which severally are of substantial mass and are made of dissimilar materials.

4. An electrical contactor comprising cooperating spaced electrodes one of which is substantially non-amalgamating with mercury and the other of which more readily amalgamates with mercury.

5. An electrical contactor comprising spaced cooperating electrodes one of which is made of a chromium iron alloy and the other of which is made of a material that more readily amalgamates with mercury.

6. An electrical contactor comprising cooperating spaced electrodes one of which is made of a chromium iron alloy and the other of which is made of nickel.

7. A contactor comprising an elongated hermetically sealed container, cooperating electrodes spaced longitudinally of the container, and a movable body of mercury contained therein, the electrode immediately adjacent to the end of said container being made of a material to which a mercury film adheres and the other electrode being made of a non-amalgamating material.

8. A contactor comprising an elongated hermetically sealed container, cooperating electrodes spaced longitudinally of the container, and a movable body of mercury contained therein, the electrode immediately adjacent the end of said container being made of a non-amalgamating material to which a

film of mercury adheres and the other electrode being made of a chromium iron alloy.

9. A contactor comprising an elongated hermetically sealed container, cooperating electrodes spaced longitudinally of the container, and a movable body of mercury contained therein, the electrode immediately adjacent the end of said container being provided with a recessed end thereby increasing the tendency of mercury to adhere thereto and the other electrode being provided with a pointed end.

10. A tiltable mercury contactor comprising an elongated container, and a body of mercury therein which is lubricated in situ by a mercury compound which also lubricates the inner wall of the container.

In witness whereof, I have hereunto subscribed my name.

LOUIS A. M. PHELAN.