This invention relates to contacting electrodes and more particularly to electrical contact elements used in making intermittent arc discharge with an arrangement wherein the planes of two flat contacting surfaces are caused to meet automatically at all times in exact coplanar relationship.

Electrical contacts are employed in everyday life in a very wide variety of apparatus. For instance, a high power circuit breaker of a power transmission line system is an extreme example of a contact; the contacts of a microswitch represents an extreme of another kind. In the latter, the power controlled is so low that usually no serious problems are presented in electrode design. However, the control of higher power levels by electric contacts involves problems of all kinds, particularly when the contacts must function reliably over a long period of time. In circuits requiring a multiplicity of controlling contacts, the failure of a single contact may have serious consequences. The operation of electrical contacts is also the limiting factor in the design of many electrical control systems, and the development of automation in modern industry has further increased the need for reliable contacts.

There is also considerable variety of electrical equipment using electrical contacts which specifically must be frequently opened and closed in time, which have to be capable of handling current surges of relatively large magnitude. A partial list would include various kinds of circuit breakers, timers, motor starters, controllers of all kinds, advertising flashers—the most common being the conventional ignition system for internal combustion engines. The last mentioned is representative example of the rapid making and breaking of an electrical circuit and of the problems of electrical contacts. For this reason the invention to be described herein will be with particular reference to such applications in internal combustion engines. It is to be understood, however, that the invention has an unlimited application to all varieties of electrical and electronic equipment which use electrical contacts and wherein the basic features of the invention can be used to improve the life and operating efficiency of the contacts.

The purpose of all electrical contacts is to perform the three operations of making a circuit, maintaining a circuit, breaking the circuit and to repeat these operations at intervals which in some cases may be extremely short and others as long as years. As might be expected, the particular physical forms and operating conditions of the electrical contact depend on the function it has to perform. The design may vary from the large circuit breaker to the delicate so-called electrostatic contacts of electronic circuits.

The usual problem, heretofore, has been that of finding and arranging electrode materials which under specified operating conditions will produce a low resistance contact, which will remain in contact for a long operating life. The outstanding cause of unreliability is the destruction of the initially smooth surfaces of the contacting electrodes leading to extensive deformation of the respective surfaces. This makes electrical contact bad or impossible. The deformation is produced by progressive erosion of the electrodes by chemical and electrical action. This erosion occurs slowly or rapidly, on a microscopic scale or over large areas, depending on the particular kind of contact concerned and on the nature of the electric circuit.

It is well-known that electrical discharges or arcs can produce marked erosion of electrodes used for contact; the make and break contacts in the ignition system of internal combustion engines is an outstanding example. Hence, if the operating conditions of the contact are such that an arc occurs (as when the potential between the electrodes equals or exceeds the ionization voltage of the gas or vapor between the electrodes) electrode erosion is to be expected. Material eroded from one electrode usually is transferred by the arc to the other electrode, producing wear and disfigurement. Such transfer of electrode material is known as arc transfer.

The useful life of the electrodes, which is generally limited by arc transfer, depends on the intensity, dwell time and frequency of occurrence of the arc, and on the contact area and material of the electrodes. Of these factors, arc intensity controls the erosion rate of the electrodes and is a function of circuit power; the other factors affect the degree of erosion over a period of time and are functions of the design and operating conditions of the electrodes. In communication circuits where power is low, erosion of the electrodes is relatively slow compared to the rate in higher power systems where potentials between electrodes can be hundreds and even thousands of volts. The electrodes in the latter would soon disintegrate without effective means for controlling the arc.

Whenever direct current is broken, arc transfer tends to develop a pit, or crater, in the anode electrode and deposit some or all the eroded material on the cathode electrode to produce an ex crescence or growth. The crater and growth are seldom exact counterparts of one another; hence, the growth is unlikely to be completely contained or enveloped in the crater when the electrodes meet to make electrical contact. It is clear that disfigurement of the electrodes by the crater and growth formations can cause failure of the contact due to high resistance connection, mechanical locking or to simply wearing away of one of the electrodes. Also, it must be remembered that in some light duty applications, as in communication networks, electrode travel is frequently very short and growths projecting only a few tenths millimeters from the electrode can render the contacts ineffective. In critical applications where extremely high degrees of continued efficiency are specified, the customary solution in the past has been not to attempt to solve the problem but to postpone it by using precious metals for contact electrodes. This is frequently impractical because of the extra expense, expense which is not justified in many applications by the longer life thereby obtained. A further technique has been to enclose the electrodes to prevent atmospheric contamination. At the same time, the enclosing means might be evacuated, pressurized with a gas, or oil filled. Another solution in some applications has been to recognize the defects of the contacts used in the past and surrender to their known limitations by making the system more accessible and easier to service when required.

Turning now from the general problem of deterioration to the problems of a specific application, in a conventional automobile ignition system the circuit make and break electrodes, heretofore referred to as breaker points, are referred to as breaker points and are abrupt as possible a flow of direct current of appreciable magnitude in a highly inductive circuit at rates up to 20,000 times or more a minute over long periods of time. This is a difficult function for the ordinary breaker points to perform effectively day in and day out when high levels of engine voltage are required and, in addition, the mechanism of the breaker points is one of the most common causes for poor engine performance. In keeping with the basically simple electro-mechanical ignition sys-
tem, it is logical and desirable that the breaker points have as long a useful life, and be as free from service requirements as economically possible and the state of the art will permit. Heretofore, in order that peak performance of the engine may not be hampered by ignition difficulties, breaker points have required relatively frequent attention and replacement, usually by trained technicians. In addition to the expense, loss of the engine or equipment, and the inconvenience and bother such service entails, the problem of adjustment and replacement is complicated by the fact that the breaker points are frequently located in confined spaces, congested and difficult of access. It is not surprising, therefore, that there has been a strong tendency to put off or delay servicing the breaker points until long after the ignition system has ceased to function efficiently and engine performance has become impaired. It follows that an inexpensive electrical contacting device having appreciably longer life than the presently conventional breaker points, and requiring far less service, is an advancement in the state of the art and an improvement in the ignition system commonly used for internal combustion engines.

The contacting area of metallic electrodes for making and breaking a circuit is normally proportional to the circuit power, and individual arc discharges generally occur at the point of closest approach between the contacting surfaces. For example, the feet of an arc discharge between ignition breaker points occupy but a very small portion of the contacting area provided and usually at a location corresponding to the shortest distance between the contacting surfaces at the instant of separation. Irrespective of ignition circuit parameters, it is of primary importance to maximum life and operating efficiency of the breaker points that the contacting surfaces be flat and constrained to meet invariably in concentric and coplanar relationship when making electric contacts. In this optimum geometric alignment of contacting points, the arc discharge normal for each part of the breaker points can occur indiscriminately and at random over the entire contacting area. Unless influenced by factors other than electrode alignment, it follows that the average disposition of the arc discharges results in a distribution that is uniform over the entire area of contacting surfaces. It is evident, therefore, that the erosion rate per unit area of contacting surface is then at the minimum.

A small axial misalignment of otherwise optimally aligned contacting planes is relatively unimportant since contacting area is not appreciably diminished and distribution of arcing is not affected by the misalignment. However, that the slightest deviation from a true coplanar meeting of flat contacting surfaces will not only reduce the contacting area considerably but concentrate arcing at a small sector at the rims of the contacting surfaces where the breaker points must, perforce, come together. The ensuing acceleration of erosion at the localized contacting area prematurely widens the initially adjusted gap between the breaker points and transfers material from one breaker point to the other at a rate which produces surface craters and growths in a comparatively short time. One started, this deterioration of the contacting surfaces increases at an increasing rate and malfunction of the ignition system occurs much sooner than when the contacting surfaces come together squarely. The majority of breaker point replacements are premature for this reason.

The customary mode of making and breaking the primary ignition circuit is to have one of the breaker points firmly affixed to the end of a pivoted rocker arm, the point making a spring-loaded contact with a mating point firmly affixed to a relatively stationary support. A cam rotating with the engine displaces the arm against the spring causing the breaker points to be briefly separated. It is apparent in this arrangement that in order for flat contacting surfaces to meet consistently in exact coplanar relationship, it is essential that the relative disposition of the members supporting the breaker points be precisely established and that consistent action of the moving member be unvarying. Heretofore, the inadequacy in design and the manufacturing precision necessary to satisfy these requirements have been precluded by economic considerations. It follows that optimum and enduring alignment of flat contacting surfaces cannot be assured in the conventional breaker point arrangement and breaker points having such surfaces are subject to early deterioration.

In order to permit some tolerance in alignment, it is common for one or both contacting surfaces of conventional breaker points to be slightly crowned, that is, slightly convex so that when the arcing point is sacrificed, the operating life and efficiency of the breaker points are reduced, and the need for service is increased. Obviously, such compromise is not a satisfactory solution to the problem.

While a coplanar meeting of flat contacting surfaces predisposes uniform distribution of the arc discharges over the entire contacting area, inhomogeneities, whether on the surface or within the structure of the electrode material, often tend to form a nucleus for local arc discharges. Heretofore, contacting devices such as ignition breaker points have been widely used for deterring development of a nucleus of this sort which would blemish which local arcing progresses from a sporadic stage to a persistent state. The subsequent increasing rate of local erosion culminates in premature failure of the electrodes in a manner similar to that induced by imperfect alignment of contacting planes. It follows that while optimum alignment is essential to uniform distribution of arc discharges over the contacting planes, discriminative arcing leading to destruction of the electrodes can be initiated by a cause other than geometric.

When contacting surfaces meet without sliding or wipping, wear from mechanical abrasion is generally a very insignificant factor in the life of the electrodes. Migration of particles from one electrode to the other when the electrodes are in contact, a phenomenon variously known as "fine transfer," "bridge transfer," "bridge erosion," or by other terms is ordinarily also an unimportant factor in electrode life. Arc transfer, then, is by far the greatest cause of electrode deterioration and it is patent that were arcing completely eliminated from between the contacting surfaces, electrode life and replacement would cease to be matters for practical consideration. It logically follows that electrode life will be lengthened to the extent that arcing is reduced.

The capacitor normally connected across the ignition breaker points reduces the intensity of the arc discharges considerably, and, in so doing, causes the spark coil primary circuit of the ignition system to be broken with sufficient speed to generate an ignition voltage in the spark coil secondary. However, from the fact that breaker point life has hereetofore been limited by the ravages of arc discharges, it is obvious that the arcing which persists despite connection of the capacitor is of an intensity level sufficiently high to be quite damaging. The efficacy of a shunt-connected capacitor in reducing arcing intensity across the breaker points is limited by required operating conditions of the breaker points, and by circuit parameters bearing on desirable critical damping of the spark coil primary circuit. Any further reduction in arcing intensity has not hereetofore been possible without repercussion on size, complexity or cost of the ignition system.

In addition to having deleterious physical effects on breaker points, arcing can also impair the operating efficiency of the ignition system. This occurs whenever persistence of the arc from the instant the breaker points open is longer than the time required for collapse of the spark coil magnetic field. On such occasions, arcing retards collapse of this field and lowers the ignition voltage induced in the spark coil secondary.

It is one object of my invention, therefore, to provide
a contacting arrangement wherein the planes of two flat contacting surfaces are caused to meet automatically and invariably in exact coplanar relationship from the beginning of service throughout the useful life of the individual electrodes, for the purpose of (1) assuring a maximum contacting area, (2) extending electrode life, and (3) improving efficiency of the electric contact. A second object of my invention is to provide means for preventing arc discharges from becoming localized on flat contacting surfaces due to causes other than failure of flat contacting surfaces to meet in true coplanar relationship. A third object of the invention is to provide means that will, without changing circuit parameters, reduce to a lower level of intensity arcing which persists between contacting surfaces notwithstanding connection of a capacitor of optimum electrical value across the electrodes, for the purpose of (1) reducing the rate of erosion of the contacting surfaces and thereby further extending electrode life, (2) permitting closer spacing of electrodes than has heretofore been practical, and (3) affording more abrupt termination of current flow in a circuit in which the speed of termination has heretofore been limited by intensity of arcing at the contacting surfaces.

A fourth object of my invention is to achieve the aforesaid objects by a simple, economical, highly compact arrangement which when necessary can be serviced by a technician of ordinary skill.

In the accomplishment of these and other objects of my invention, and relating more specifically but not exclusively to application to the common ignition system for internal combustion engines, I provide a ring-shaped electrode having a flat contacting surface, at the end of a rocker arm. The relatively stationary contacted electrode resembles the movable electrode and is a part of an assembly of parts having a hemispherical shape. The curved portion of the hemispherical assembly, hereinafter referred to as hemispheric, is positionally seated in a socket contained in a supporting member, in the manner of a ball and socket disposition.

A feature of the invention is retention of the hemispheric shape in its socket by magnetic attraction. Another feature is the high transient voltage that tends to appear across electrodes 8 and 12 whenever the circuit is broken. However, while arcing intensity is thereby reduced to a level permitting the magnetic field of primary coil 20 to collapse with a speed sufficient to induce an ignition voltage in secondary coil 26. The current in the primary circuit is limited to a value just enough to erode contacting faces 6 and 10 at a rate that necessitates frequent servicing or replacement of the electrodes.

In my invention the make and break actuation of the electrodes is similar to that shown in FIG. 1, but the electrode contacts are of markedly different configuration and construction from those heretofore employed. Referring now to FIG. 2, electrode 28, affixed to arm 2 (shown in phantom), is ring-shaped and constructed of a suitable non-magnetic metallic material having a contacting plane 30 indicated at X—X. Arm 2 is of non-magnetic material, at least in the vicinity of electrode 28, in order that it may have no influence on a magnetic field near this electrode. The other electrode comprises a generally hemispherical electrode button 32 which is pivotally mounted in a ball-joint arrangement in a socket 34 of a support 36. The latter is secured to a grounded member or bracket in the same way as electrode 12 of FIG. 1.

In the preferred embodiment described herein, the assembly of electrode button 32 is composed of four firmly joined parts. Center part 38 is a magnetic core of high energy permanent magnet material such as Alnico 5. Immediately surrounding core 38 is a ring-shaped electrode 48 of suitable non-magnetic metallic material upon
the surface 40 of which the surface 30 of electrode 28 makes physical and electrical contact. At the peripheral edge of the hemispherical button 32 is a ring 42 having essentially a triangular cross-section and made of a material having high magnetic permeability such as Norway iron. Completing the hemispherical shape and volume of button 32 is a fourth part 44 made of a non-magnetic but preferably electrically conducting material.

The diametrical plane of hemispherical button 32 consists of the surface of one end of ring 32 is a ring 42 having a surface 40 of ring electrode 48 and a surface of ring 42, all being on a common plane Y—Y which is perpendicular to the axis of the magnetic core 38.

The support 36 can be made of any material having good electrical conductivity and high magnetic permeability, such as Norway iron. The socket or cup 34 formed in support 36 has a configuration to suit button 32, and the depth is desirably somewhat shallower than the button radius so that plane Y—Y is somewhat above surface 46 of support 36 to facilitate measurement and adjustment of electrode spacing. Since the button is retained in socket 34 of support 36 only by magnetic attraction, it is free to pivot in its socket in any direction. It will be noted from FIG. 2 that when arm 2 presses electrode 28 against electrode surface 40, which is coincident with plane Y—Y of button 32, the latter will adjust itself in its socket until its plane Y—Y is coincident in its meeting with plane X—X of electrode 28. The alignment of plane Y—Y with plane X—X is thus automatically maintained and the full area of the annular contacting surface 30 of electrode 30 makes electrical connection with a corresponding area on the annular contacting surface 40 of ring electrode 48. The inside and outside diameters of ring electrode 48 are somewhat smaller and somewhat larger respectively than the equivalent diameters of ring electrode 28 to minimize the possibility of the latter touching either the center core 38 or the outer, peripheral ring 42. It is to be understood that the areas of surfaces 30 and 40 are to be properly proportioned with respect to the power of the circuit. It is also to be understood that button 32 is constantly in good electrical contact with support 36.

Since the flat contacting surfaces 30 and 40 are constrained to meet always in true coplanar relationship, maximum contacting area is assured. Unless influenced by the factor other than mis-alignment, arc discharges incident with separation of these surfaces will occur indiscriminately and at random over the entire area of the contacting surfaces. Erosion due to arc transfer is therefore not confined to some local area on the contacting surfaces, which condition, as has been explained, is a defect common in ordinary contacting devices, leading generally to malfunction of an ignition or another type of circuit. On the contrary, the spreading of arc discharges over the entire contacting area of the electrodes results in minimizing the erosion rate per unit area of contacting surface, and aids materially in preserving the contacting surfaces 32 and extending electrode life. Furthermore, contact resistance tends to be lower and more uniform due to the entire contacting area meeting with equal pressure at all points. It is clear that the purposes of the first mentioned object of my invention are accomplished in the manner just described.

In FIG. 3 it can be seen that the path of the magnetic field of magnetic core 38 is through a portion of the support 36, through the ring 42, and radially across the exposed surface 40 of ring electrode 48 at the plane Y—Y of button 32. As indicated by the dash arrows in FIG. 3 there exists at the surface Y—Y a radial magnetic field which bridges an annular gap 50, the gap being in the surface 40 of ring electrode 48. Due to the cross-sectional shape of ring 42, the path of minimum magnetic reluctance coincides with the exposed surface 40 of ring electrode 48, hence the plane of the latter coincides with the plane of greatest field strength in the gap 50. As indicated in FIG. 4 by solid arrows in that part of the magnetic field having the shortest path and the greatest field strength.

Arc discharges occurring between electrode surfaces 30 and 40 at the instant of break must take place wholly within the annular magnetic gap 50 and on a plane where the magnetic field is strongest. The electrons and ions which constitute the magnetic charge migrate from one electrode to the other in opposite directions in the electric field between surfaces 30 and 40 but in a common path or beam that is normally perpendicular to the plane of the radial magnetic field bridging the annular gap. Because of the well known affect of a magnetic field on charged moving particles, the arc elements are subjected to a force which deflects them in a common sideways direction that is ever perpendicular to the radial flux lines in the annular gap. An arc discharge as a whole, from its inception until its extinction, is therefore coerced by the magnetic field to digress from a normal fixed path between the electrodes and to effect a circular excursion over electrode surfaces 30 and 40 in an orbital trend about core 38. Erosion and vaporization of electrode material is hindered by the rapid movement of the arc feet across the contacting surfaces and the arc discharge tends to pass into a much less harmful glow discharge before becoming completely extinguished by the weakening of the electric field as the gap between surfaces 30 and 40 is widened.

It is evident that control of arc discharges in this manner inhibits formation of a nucleus for local arc discharges that could otherwise be created by inhomogeneities on the surface or within the structure of the electrode material, or by any other cause against a true coplanar alignment of surfaces 30 and 40 is ineffective. By this means, then, is the second object of my invention accomplished.

Since the electrons and ions of any arc discharge between electrodes 28 and 48 are exposed to the magnetic deflecting force in annular gap 50 during the entire time of their transit from one electrode to the other, it is evident that the deviation from their normal direct path between the electrodes becomes increasingly greater with progress in transit and that the deflection is maximum at the instant of impingement on the arc column toward which they migrate. The electrons, having a much less mass, are deflected considerably more than the ions and into an elongated path that has a tendency to spiral around core 38. The extent to which the deflected electron path spirals is a function of the ratio of the electric field strength between the electrodes to the magnetic field strength in annular gap 50. When the magnetic field is strong compared to the electric field, a condition which should be accentuated as greatly as possible by design, the spiraling characteristic is considerable and the electron path is correspondingly lengthened between the electrodes.

It is to be remembered that ionization of a region between electrodes requires free electrons to be present in that region. Because of the deflection of the electrons from their normal direct path between electrodes, ionization of this path is precluded and occurs instead in the diverged electron path. It is evident, therefore, that an arc discharge, as a whole, for a given gap width between electrodes 28 and 38 is stretched out and elongated to the extent that the deflected electron path is longer than the normal path.

It is to be understood that such elongation of an arc discharge occurs simultaneously and in combination with the reaction of the arc discharge to the magnetic field in annular gap 50 wherein the arc discharge as a whole tends to orbit about 38 with its feet moving in a circular direction on electrode surfaces 30 and 40, as has been previously explained.
3,042,778

In the conventional breaker point arrangement and other common contacting methods, the arc is drawn out and the electric field becomes progressively weaker as the gap between electrodes is widened. When the gap is widened to the extent that the electric field is too weak to sustain ionization of the extended arc discharge, the arc is suddenly extinguished. In my invention, however, in addition to its other features the arc discharges between electrode surfaces are lengthened or stretched out to extinguish not only by widening of the gap between these surfaces but by deflection of the electrons normally present in arc discharges. This deflection occurs for a given speed of separation of the electrodes, and for a given electrical potential across them, arc discharges are extinguished sooner after parting of the electrodes and at a narrower gap between the electrode surfaces. It follows that by lessening the dwell of arc discharges between electrodes, erosion of the electrode contacting surfaces is reduced and life of the electrodes is increased. Furthermore, extinguishment of arc discharges at lesser separation of the electrodes permits a closer spacing than has hitherto been practical, resulting in less wear on actuating parts such as cams, cam followers, pivot shafts and bearings, etc., in less noise, in less bounce, and in more precise and uniform timing, particularly at high rates of speed in making and breaking a circuit. An additional advantage is more abrupt termination of current flow upon separation of the electrodes, thus resulting in higher ignition efficiency. In augmenting, by the means explained, the distortion and extension of arc discharges normally occurring when electrodes are separated, the purposes in the third object of my invention are accomplished.

A variation in design of electrode button 32 and support 36 is shown in FIG. 5. The electrode indicated at 52 in FIG. 5 is identical to that shown in FIG. 2 except that cylindrical core 54 of the variation is made of a material having a high magnetic permeability such as Norway iron; support 56 would be made of a high energy permanent magnet material such as Alnico 5, magnetized in a manner to produce a field through core 54 as indicated by the arrows in FIG. 5.

A hole 58 in the bases 36 and 56 permits the contact button to be conveniently poked out of its socket with a thin rod when removal is necessary.

While the foregoing description is in terms of using permanent magnetic materials, the same results can be achieved with electromagnetically created fields. Other minor variations of this preferred embodiment will be apparent to those skilled in the art; and, therefore, it is not my intention to confine the invention to the precise form herein shown, but rather to limit it in terms of the appended claims.

I claim:

1. An electrical contact device comprising first and second contact members having first and second contact surfaces respectively, said first surface being non-magnetic, said second member having a magnet for producing a magnetic field between said contact surfaces and means for controlling said magnetic field in substantially coplanar relation with said second contact surface, said magnetic field arranged to cause movement of the path of arc-carrying ions in a direction perpendicular to the axes of said members while simultaneously causing distortion of said path of arc-carrying ions between said members.

2. An electrical contact device comprising first and second contact electrodes, said first electrode having a ring-shaped non-magnetic end face; and said second electrode having an end surface arranged for engagement with said end face, a single magnet, and means cooperating with said magnet to provide an annular magnetic field confined along said surface.

3. An electrical contact device comprising a hemispherical contact member pivotally seated in a socket member of magnetically permeable material, said hemispherical contact member comprising a magnetic core coaxial with the principle hemispherical axis, a non-magnetic ring surrounding said core, and a ring of permeable magnetic material at the periphery of said non-magnetic ring, said member hemispherical having a planar contact surface and a radial magnetic field concentrated at said contact surface.

4. A hemispherical contact member having a planar contact surface and comprising a core of magnetically permeable material surrounded by a ring of non-magnetic material, and a magnetically permeable material forming a ring at the periphery, said member having a radial magnetic field at the contact surface thereof when seated pivotally in a socket formed in a magnetic material.

5. An electrical contacting device having first and second self-aligning contact electrodes, said first contact electrode having an annular substantially flat contact surface, said second electrode having a substantially hemispherical body with a round substantially flat contact surface, said hemispherical body pivotally supported in a socket of complementary configuration and retained for relative movement therein by direct magnetic attraction thereto, whereby substantially coplanar surface contact is achieved between said contacting surfaces, said hemispherical body comprising a center core of permanent magnetic material, a body portion including the contact surface of said hemispherical body surrounding said body portion and the contact surface of said hemispherical body made up of non-magnetic, electrically conductive material, and a peripheral ring surrounding said contact surface composed of magnetically permeable material.

6. Self-aligning contact electrodes comprising first and second electrodes having first and second planar contacting surfaces respectively, said first surface made of non-magnetic material, said second electrode including a supporting structure having a socket portion, a ball portion pivotally seated in said socket portion, and a magnet exerting a magnetic force on both portions whereby to retain said ball portion in said socket portion, said magnet disposed so that most of the path of its magnetic field is through said ball and socket portions, with a portion of said path extending radially across said second planar contacting surface.

7. Self-aligning contact electrodes comprising first and second electrodes having first and second planar contacting surfaces respectively, said second electrode including a supporting structure having a socket portion, a ball portion pivotally seated in said socket portion, and a magnet exerting a magnetic force on both portions whereby to retain said ball portion in said socket portion, said second surface including a non-magnetic portion and said electrodes mounted so that said first electrode contacts said second electrode only at said non-magnetic portion.

8. Self-aligning contact electrodes comprising first and second electrodes having first and second planar contacting surfaces respectively, said second electrode including a supporting structure having a socket portion, a ball portion pivotally seated in said socket portion, and a magnet integral with said ball portion exerting a magnetic force on both portions whereby to retain said ball portion in said socket portion.

9. Self-aligning contact electrodes comprising first and second electrodes having first and second planar contacting surfaces respectively, said second electrode including a supporting structure having a socket portion, a ball portion pivotally seated in said socket portion, and a permanent magnet forming part of one of said portions and exerting a magnetic force on both portions whereby to retain said ball portion in said socket portion, said magnet having a magnetic field extending radially across said second contact surface, said socket portion having a hole.
at a point in the bottom thereof for insertion of a tool for poking said ball portion out of said socket portion.

10. A hemispherical contact member having a planar diametric contact surface and comprising, a magnetic core coaxial with the principal hemispherical axis, a non-magnetic ring surrounding said core and forming at least part of said contact surface, and a ring of magnetically permeable material at the periphery of said non-magnetic ring, said contact member having a magnetic field which passes through and is shaped by said ring of magnetically permeable material with the path of minimum magnetic reluctance coinciding with said contact surface, whereby said magnetic field is concentrated at and extends radially across said contact surface.

11. Self-aligning contact electrodes comprising first and second electrodes having first and second planar contacting surfaces respectively, said second electrode including a supporting structure having a socket portion, a ball portion pivotally seated in said socket portion, said ball portion comprising a center core of a material of high magnetic permeability and a peripheral ring of high magnetic permeability surrounding said second contact surface, and a magnet integral with said socket portion exerting a magnetic force on both portions whereby to retain said ball portion in said socket portion, said magnet disposed so that most of the path of its magnetic field is through said ball and socket portion with a portion of said path extending radially across said second planar contacting surface.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Inventor</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re. 21,087</td>
<td>Rankin</td>
<td>May 16, 1939</td>
</tr>
<tr>
<td>1,771,905</td>
<td>Uher</td>
<td>July 29, 1930</td>
</tr>
<tr>
<td>2,334,562</td>
<td>Latta</td>
<td>Nov. 16, 1943</td>
</tr>
<tr>
<td>2,411,892</td>
<td>Peters</td>
<td>Dec. 3, 1946</td>
</tr>
<tr>
<td>2,411,893</td>
<td>Peters</td>
<td>Dec. 3, 1946</td>
</tr>
<tr>
<td>2,611,059</td>
<td>Immel et al.</td>
<td>Sept. 16, 1952</td>
</tr>
<tr>
<td>2,671,148</td>
<td>Schulenburg</td>
<td>Mar. 2, 1954</td>
</tr>
<tr>
<td>2,725,446</td>
<td>Slepian</td>
<td>Nov. 29, 1955</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>494,131</td>
<td>France</td>
<td>May 22, 1919</td>
</tr>
<tr>
<td>655,491</td>
<td>Great Britain</td>
<td>July 25, 1931</td>
</tr>
</tbody>
</table>
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,042,778

July 3, 1962

Albert E. Anderson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 10, line 6, for "member hemispherical contact" read -- hemispherical contact member --.

Signed and sealed this 20th day of November 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents