July 3, 1962 J. S. HAWKINS 3,042,774

VACUUM SWITCH

Filed March 27, 1959 2 Sheets-Sheet 1

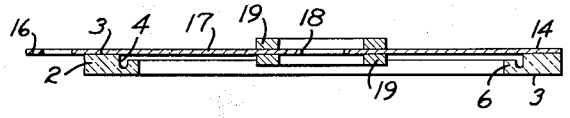


Fig. 3

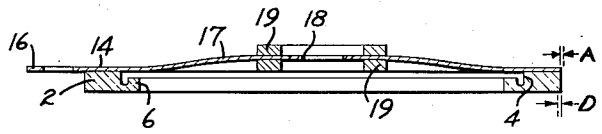


Fig. 4

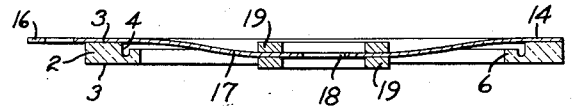


Fig. 5

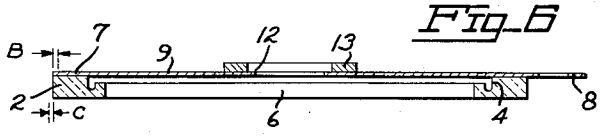


Fig. 6

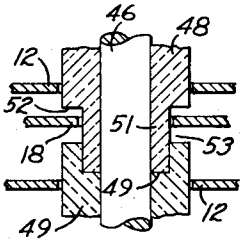


Fig. 9

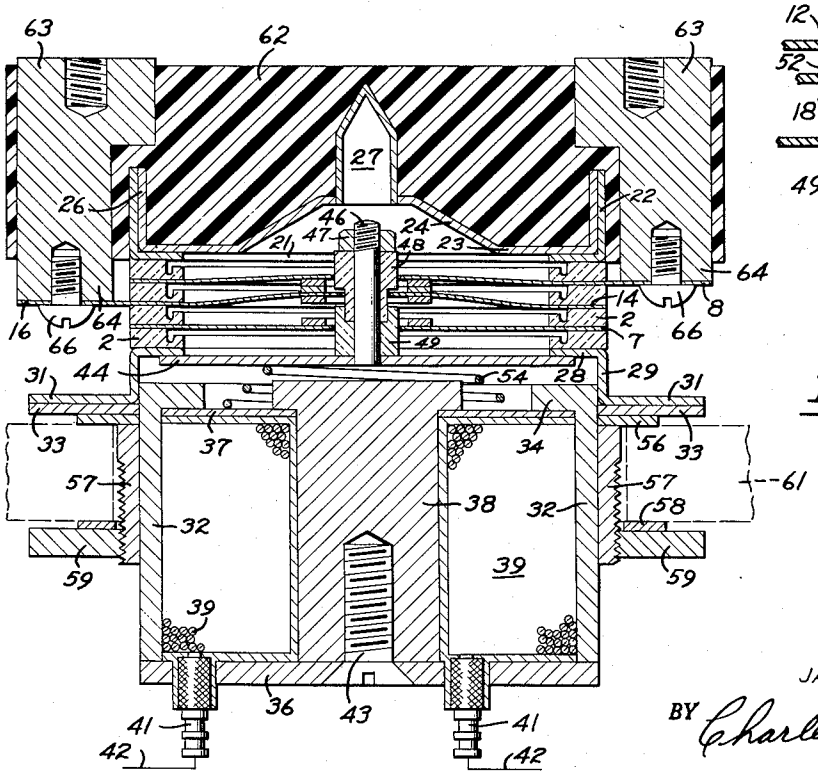


Fig. 1

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Filed March 27, 1959 2 Sheets-Sheet 2

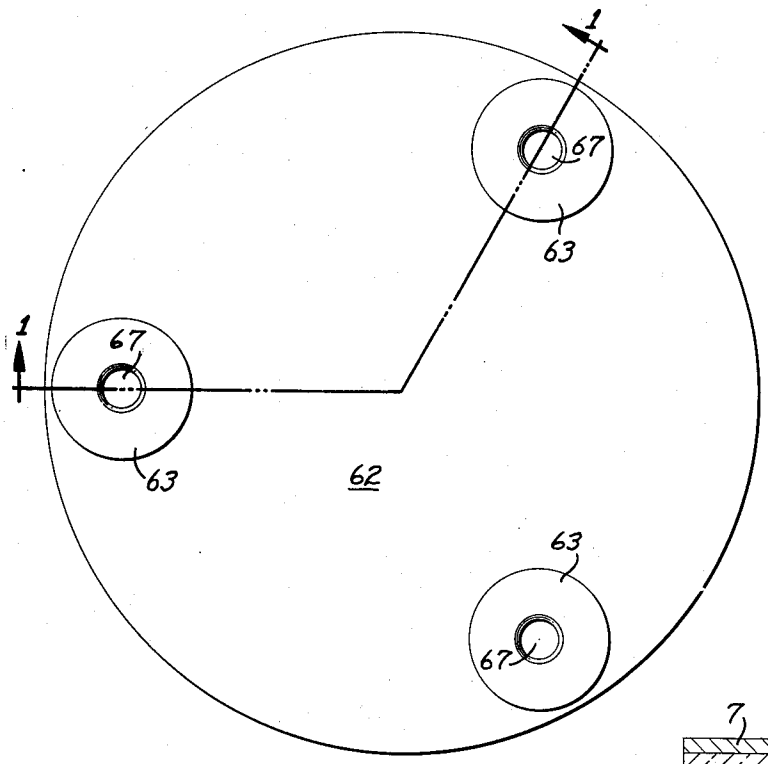


Fig_2

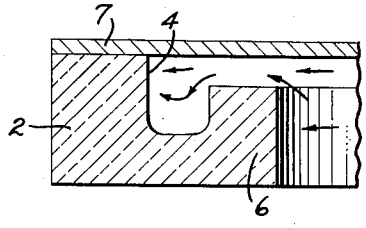


Fig_8

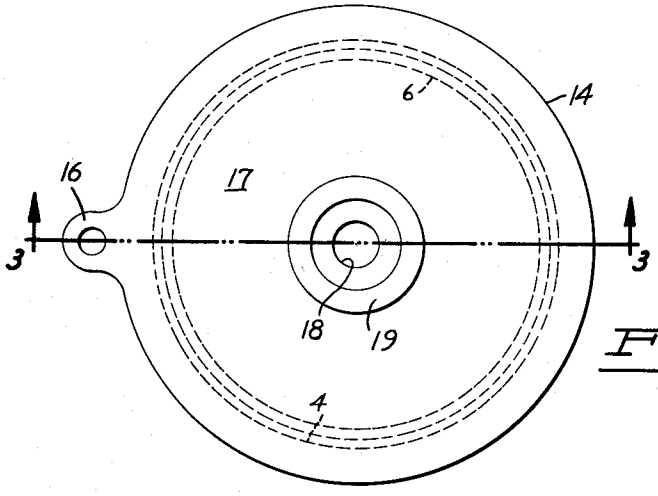


Fig_7

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3,042,774

VACUUM SWITCH

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Filed Mar. 27, 1959, Ser. No. 802,478
19 Claims. (Cl. 200—104)

My invention relates to multiple pole-double throw switches or relays, and particularly to a three pole-double throw miniature vacuum switch or relay.

One of the objects of the invention is the provision of a switch the major portion of which may be brazed in one operation, thus decreasing production time and ultimate cost.

Another object is the provision of a vacuum switch in which final adjustment is unnecessary.

Another object of the invention is the provision of a double-throw vacuum switch having a built in snap-action of the movable contact in both directions.

Still another object is the provision of a solenoid operated vacuum switch requiring less coil power than conventional solenoid operated switches.

A still further object is the provision of a vacuum switch having greater contact pressure and greater contact area than comparable switches.

Still another object is the provision of a miniature vacuum switch suitable for low and medium voltage three-phase industrial and missile applications.

Another important object is the provision of a miniature three pole-double throw vacuum switch in which the contacts of one section of the switch are effectively shielded from the contacts of the other section, thus permitting three-phase make and break operation in the same envelope.

The invention possesses other objects some of which with the foregoing will be brought out in the following description of the invention. I do not limit myself to the showing made by the said description and the drawings, since I may adopt variant forms of the invention within the scope of the appended claims.

Referring to the drawings:

FIG. 1 is a vertical half sectional view taken in the plane indicated by the line 1—1 in FIG. 2.

FIG. 2 is a plan view showing the arrangement of external terminals.

FIG. 3 is a vertical half sectional view of a dielectric ring and the movable contact ring in assembled position prior to being brazed. The plane of section is indicated by the line 3—3 in FIG. 7.

FIG. 4 is a view similar to FIG. 3, but showing the dielectric and movable contact ring assembly after brazing and cooling and showing the contact ring snapped into its upper position.

FIG. 5 is a vertical half sectional view of the dielectric and movable contact ring assembly showing the contact ring snapped into its lower position.

FIG. 6 is a vertical half sectional view of one of the fixed terminal rings shown brazed to a dielectric ring.

FIG. 7 is a plan view of the contact ring detached from the assembly and illustrating the relationship between the inner periphery and contact area thereof.

FIG. 8 is a fragmentary sectional view of one of the dielectric rings, with a terminal ring attached, and illustrating the shield means interposed between the inner periphery of the dielectric ring and the switch contacts.

FIG. 9 is a fragmentary vertical sectional view illustrating the close confinement of the dielectric bushings by the inner peripheries of the terminal and contact rings.

FIGS. 1 through 7 are drawn to a scale approximately three times actual size, FIG. 8 is drawn to a scale approximately twelve times actual size, and FIG. 9 is enlarged approximately six times actual size.

The exacting requirements which conventional switch gear must meet in order to insure its reliability and suitability for incorporation in modern environments such as land, sea, air and space equipment, results in the virtual necessity of hand processing each conventional device to bring it within the close tolerances necessary for reliable operation. This custom processing increases production time and cost, and necessitates elaborate testing and inspection procedures to insure compliance with requirements. It is therefore the broad object of the present invention to provide a switch in which the elements are of a nature permitting sub-assembly thereof and heating to brazing temperatures to integrally and hermetically unite the sub-assemblies into composite units requiring very little additional assembly or further processing. The brazing temperatures utilized are of a magnitude to adequately heat treat those elements requiring such treatment.

Broadly considered, the vacuum switch of my invention comprises an evacuated envelope formed by a series of axially aligned dielectric rings, preferably metallized ceramic, having metallic terminal and contact rings integrally and hermetically interposed therebetween in a selected cooperative relationship. Each opposite end of the ceramic-metal ring complex is hermetically closed by a metallic end plate structure integrally brazed to an end ceramic ring of the ceramic-metal ring complex. Within the envelope thus formed are provided fixed and movable contacts integral, respectively, with the terminal and contact rings, and movable into and out of engagement to make and break a circuit through selected pairs of such rings. Armature means are provided within the envelope cooperating with an energizable coil outside the housing for effecting movement of the movable contact. To prevent the deposit of conductive vaporized contact metal on the inner periphery of each ceramic ring, which if permitted to accumulate will build up a conductive path between adjacent terminal and contact rings, each ceramic rings is provided with an integral shield which cooperates with associated surfaces to prevent the accumulation of a continuous conductive layer. A tubulation for evacuating the envelope is provided on one of the end plate structures, and a block of dielectric material embedding the tubulation and the associated end plate structure, provides protection for the tubulation and also serves to support external terminals conductively connected to the terminal and contact rings, and providing convenient means for connecting the switch into a circuit.

In more specific terms, the miniature high power vacuum switch of my invention comprises a plurality of annular ceramic rings **2** having opposite metallized sides **3**. On its inner peripheral surface **4**, each ceramic ring is provided with an integral concentric reentrant flange **6**, radially spaced inwardly approximately 0.015" from the surface **4** of the ceramic ring and constituting a shield against vaporized contact material. In a ceramic ring such as the one illustrated, in which the height ranges from 0.086" to 0.088" and the radial thickness amounts to approximately 0.217", the differentiation in height between ceramic ring and shield flange may conveniently range from 0.010" to 0.017".

Hermetically brazed about its outer peripheral portion between adjacent ceramic rings of selected pairs thereof and axially aligned therewith, is an annular metallic terminal ring **7**. The ring is provided with an integral radially outwardly extending apertured tab **8** constituting a terminal lead, and extends radially inwardly in an annular portion **9** provided adjacent its inner periphery **12** with an integral concentric contact **13**. The terminal ring is preferably fabricated from thin gauge NiFe alloy having a rate of contraction somewhat greater than the rate

of contraction of the ceramic rings to which it is brazed. During heating the two materials expand at respective rates. After heating and brazing to integrally unite the parts, the joined parts are simultaneously cooled. Since the parts are now integrally united, they can no longer contract at their respective rates. The rate of contraction of each is now modified by an interdependence upon the contraction of the other part. Thus, the NiFe ring is prevented from contacting as much as it had expanded, and the resulting tension in the NiFe ring draws the ring tightly across the ceramic ring, thus causing the ceramic ring to be compressed. This phenomenon is illustrated quantitatively in FIG. 6, where the distance B represents the amount, greatly exaggerated, which the terminal ring is prevented from contracting, and the distance C represents the amount, again greatly exaggerated, which the ceramic ring is compressed by tension in the NiFe ring.

The ceramic-metal ring complex is completed by hermetically and integrally interposing between the pairs of ceramic rings carrying the terminal rings, an annular metallic contact ring **14**. This ring is axially aligned with the ceramic rings and terminal rings and is provided with a radially outwardly extending apertured lug **16** constituting an external terminal lead. Within the ring assembly the contact ring is provided with an integral inwardly extending annular domed portion **17** provided adjacent its inner periphery **18**, and on both sides of the ring, with integral concentric contacts **19** axially aligned with and adapted to engage with and disengage the fixed contacts **13** on the juxtaposed terminal rings. The contact ring **14** is distinguished from the terminal rings **7** by having a slightly smaller central aperture, as best shown in FIG. 1, and by being fabricated from a different material.

The contact ring **14** is fabricated from thin gauge molybdenum in sheet form, which when stamped into the form shown in FIG. 3 and assembled as an element in the ceramic-metallic ring complex exhibits characteristics markedly different from those exhibited by the terminal rings. In comparison with the ceramic rings to which it is brazed, the molybdenum contact ring expands and contracts less than the ceramic rings with variations in temperature. After heating and brazing, the integrally joined parts are cooled simultaneously, whereupon the relatively greater and more rapid contraction by the ceramic rings causes a radially inwardly directed compressive force to be exerted on the outer peripheral portion of the molybdenum contact ring, thus causing the radially inwardly extending annular portion **17** to compensate for a relatively less and slower contraction by being displaced into a domed shaped. FIGS. 3 and 4 illustrate the relationship of the parts before and after heating to a brazing temperature and subsequent cooling. As with the terminal rings, this phenomenon is illustrated quantitatively in FIG. 4, where the distance A represents the amount, again greatly exaggerated, which the ceramic rings force the molybdenum contact ring to contract. The distance D represents, greatly exaggerated, the amount the ceramic rings are prevented from contracting by the compressive stress created in the molybdenum contact ring.

To form the ceramic-metal ring complex, the terminal and contact rings, both flat, are stacked with the individual metallized ceramic rings with brazing compound applied, in the relationship shown in FIG. 1. This assembly is then heated in an oven to a high brazing temperature at which temperature the contiguous portions of ceramic and metal rings hermetically coalesce into a light weight unitary complex of great rigidity. Upon being cooled and removed from the oven, it will be found that the different contraction coefficients of the ceramic, terminal and contact rings have effected tensioning of the terminal ring and compression of the contact ring as previously described.

As illustrated in FIGS. 1, 4 and 5, compressing the

contact ring to form a dome therein results in displacement of the inner peripheral portion of the ring to one side of the plane of the outer periphery of the ring. If pressure is now applied to the convex side of the displaced central portion of the contact ring in a direction parallel to the axis thereof, the contact-carrying annular portion will be caused to snap to the opposite side of the plane of the outer periphery of the contact ring. It has been found that to effect such side-to-side displacement, pressure need be applied only until the annular portion is just past the plane of the outer periphery. The compressive stress built up in the annular portion by bringing it into this position then exerts itself to snap the annular portion to its outer extremity. These alternate positions are illustrated in FIGS. 4 and 5. As will be apparent from FIG. 1, when the contact ring is displaced to either side, one of its contacts **19** abuts the fixed contact **13** arranged on a juxtaposed terminal ring. The parts are proportioned so that resilient abutting engagement is effected before the contact ring reaches its outer extremity. This results in the contacts **19** on the contact ring being resiliently pressed hard against the fixed contacts by the inherent resilience of the compressed contact ring. Faster closing, less vibration and reduced contact resistance thus result.

Hermetically closing one end of the hollow ceramic-metal ring complex is an end plate structure comprising an annular plate **21** brazed to the end dielectric ring, and provided with an outwardly extending integral cylindrical flange **22**. Supported on the annular plate **21** and fitting snugly within the cylindrical flange is a cover plate **23** having a raised central portion **24** and a cylindrical peripheral flange **26** concentric with the flange **22**. The outer ends of both flanges are flush and lend themselves to heliarc brazing to hermetically seal this end of the hollow ceramic-metal ring complex. Brazed to the cover plate and communicating with the interior of the hollow complex is a tubulation **27** useful for evacuating the switch envelope.

Hermetically sealing the other end of the hollow ceramic-metallic ring complex is another end plate structure comprising an annular plate **28** hermetically brazed to the end dielectric ring and provided with an integral cylindrical flange **29** extending from its outer periphery. A radially outwardly extending integral flange **31** cooperates with the cylindrical flange **29** to form a seat on which is integrally and hermetically supported the inner end portion of a hollow cylindrical housing **32**. A radially outwardly extending flange **33** brazed on the housing adjacent its inner end is provided to lie against the flange **31**. The outer peripheries of the flanges **31** and **33** are flush and facilitate heliarc brazing to hermetically seal this union. Heliarc brazing at this point and also at the peripheries of flanges **22—26** permit easy disassembly of the switch for salvage purposes or repairs, while insuring an integral composite construction of light weight and great rigidity. The housing is preferably fabricated from magnetizable steel, and is provided on its inner end portion with a radially inwardly extending integral flange **34**, and at its other end with a detachable magnetizable cover plate **36**.

Hermetically sealing the inner end of the hollow cylindrical housing is a non-magnetizable transverse wall **37**. The wall is annular in form and spaced intermediate the ends of the housing, the outer peripheral portion of the wall being integrally and hermetically brazed to the housing wall, while the inner peripheral portion of the wall is integrally and hermetically united to a magnetizable core **38**. The outer end of the core cooperates with the detachable cover plate **36** to detachably retain and enclose an energizable coil **39** within the hollow housing **32**. Terminals **41**, extending through the cover plate provide means for connecting the coil with control circuit leads **42**. A screw **43** threaded into the outer end of the core clamps the cover plate to the core and hous-

ing to complete the magnetic path at this end of the housing.

Within the evacuated hollow chamber means are provided responsive to the magnetic field generated by the energized coil to move said movable contact into and out of engagement with adjacent fixed contacts. Armature 44 positioned for axial movement within the envelope between the annular plate 28 and the inner ends of housing 32 and core 38, carries a centrally disposed perpendicular stem 46 brazed at its lower end on the armature and threaded at its upper free end to receive a clamp nut 47.

Detachably mounted on the stem are a pair of upper and lower axially aligned interengaging dielectric bushings or sleeves 48 and 49. As shown in FIG. 1, interengagement of the bushings is effected by a reduced section 51 of bushing 48 seated in a rabbet in bushing 49. A shoulder 52 formed in the bushing 48 cooperates with an adjacent portion of the reduced section and the upper end of the bushing 49 to provide a circumferential groove 53 into which the inner peripheral portion 18 of the movable contact ring extends to a loose sliding fit with that portion of the reduced section 51 constituting the bottom of the groove. The clamp nut 47 retains the bushings in the relationship shown, however, if desired the bushings may be integrally united as by brazing. A coil spring 54 interposed between the armature and the wall 37 resiliently urges the armature away from the inner end of the core and into the position shown.

To mount the switch, a stop collar 56 and a threaded sleeve 57 are brazed to the housing adjacent the flange 33. The sleeve and stop collar cooperate with a lock washer 58 and nut 59 to detachably mount the switch in an apertured panel 61, shown in dash lines.

Means are provided protecting the end plate structure 21—26 and the tubulation attached thereto from accidental injury, and also providing a means for supporting and connecting the external terminal tabs 8 and 16 into a circuit. Molded about the upper end plate structure 21—26, is a block 62 of synthetic resinous material of high dielectric strength. The block conforms to the shape of the end plate structure, and is provided with conductive terminal plugs 63 embedded therein at circumferentially equally spaced intervals as shown in FIGS. 1 and 2. The lower end 64 of each terminal plug extends below the bottom of the block 62 an amount corresponding to the distance the associated terminal tab is spaced therebelow, and a screw 66 detachably and conductively secures each external tab to the associated terminal plug. The upper end of each terminal plug is bored and tapped as at 67 to provide a connecting means for leads of the circuit to be controlled.

In operation, the switch contacts are resiliently retained in the position shown by the pressure exerted by the domed contact ring tending to expand to its outermost limit. Energizing the coil causes a magnetic field to be generated, which pulls the armature and attached stem downwardly into engagement against the inner end of the core and housing and thus completes the magnetic circuit. Downward movement of the stem causes the inner peripheral portion of the contact ring to be engaged by the shoulder 52, which flexes the domed contact ring inwardly until it just passes the plane of the outer peripheral portion. At this point the contact ring tends to snap downwardly to the extreme position shown in FIG. 5. Before it reaches this position, however, it engages the fixed contact 13, and with its own intrinsic resilience added to that of the magnetic force pulling on the armature, the contacts are resiliently held in tight conductive engagement. When the coil is deenergized, the coil spring 54, which has been compressed by downward movement of the armautre, overcomes the intrinsic resilience in the contact ring and displaces it outwardly to its normal "at rest" position shown in FIG. 1.

It should be noted that upon separation of the movable contact from the fixed contacts, any vaporized contact material resulting from the formation of an arc is prevented from migrating past the inner peripheries of the terminal rings or the contact ring by the close confinement of the dielectric bushings by the inner peripheries of these rings. The terminal and contact rings cooperating with the bushings and ceramic rings 2, thus provide two substantially isolated contact chambers within which vaporized contact metal is contained. As shown best in FIG. 8, the shield 6 on each ceramic ring 2 prevents deposit of a continuous conductive layer of such vaporized metal. It has been found that vaporized contact metal will adhere to the inner periphery of the shield and to a portion of the inner periphery of the ring itself, but such vaporized material will not migrate into the channel between the shield 6 and ring 2. Vaporized contact metal is thus caused to condense in a manner which precludes formation of a conductive path between the terminal and contact rings.

I claim:

1. A vacuumized switch comprising a plurality of metallized dielectric rings, a metallic terminal ring interposed between two adjacent dielectric rings, a contact ring spaced from said terminal ring and supported on one of said dielectric rings and movable into or out of engagement with said terminal ring, said terminal and contact rings being integrally united to the associated dielectric rings to form a hermetically tight ring assembly, an end plate structure hermetically closing each opposite end of the ring assembly to form a hermetically sealed envelope, and switch actuating means supported on said envelope and operatively connected with the contact ring to selectively move the contact ring into or out of engagement with said terminal ring to make or break a circuit therethrough.

2. The combination according to claim 1, in which said terminal ring is provided with radially inwardly and outwardly extending portions providing respectively a fixed contact within the envelope and a terminal lead outside the envelope.

3. The combination according to claim 1, in which one of said end plate structures includes an annular plate, a hollow housing integrally united thereto adjacent its inner periphery, a transverse wall integrally interposed hermetically between the ends of the housing, and a magnetizable core fixed on said wall and extending on both sides thereof.

4. The combination according to claim 1, in which said contact ring is provided with radially inwardly and outwardly extending portions providing respectively a movable domed contact portion within the envelope and a terminal lead outside the envelope.

5. The combination according to claim 1, in which said switch actuating means includes an energizable coil outside the envelope, a core extending into the envelope and said coil, a coil-responsive armature movably supported within the envelope, and spring means normally urging the armature away from the core within the envelope.

6. The combination according to claim 4, in which shield means are provided integral with said dielectric rings and interposed between said dielectric rings and said domed contact portion of the contact ring.

7. The combination according to claim 4, in which means are provided electrically insulating said switch actuating means from said terminal and contact rings.

8. The combination according to claim 4, in which said switch actuating means includes an energizable coil outside the envelope and a coil-responsive armature movably supported within the envelope, said armature having a stem fixed thereto and to said movable domed portion of the contact ring to effect movement thereof in one direction when said armature moves in response to said

energized coil, and spring means within the envelope to move the armature and said domed contact portion of the contact ring in the opposite direction when said coil is deenergized.

9. The combination according to claim 4, in which a terminal ring is provided spaced on each side of said contact ring and movement of said domed contact portion of the contact ring in one direction makes a first circuit through one terminal ring and movement of said domed contact portion in the opposite direction breaks said first circuit and makes a second circuit through the other terminal ring.

10. The combination according to claim 9, in which said contact ring is electrically insulated from said terminal rings by said dielectric rings and therewith and with said terminal rings form first and second chambers within which said first and second circuits, respectively, are made and broken.

11. In a vacuumized switch, the combination comprising a plurality of axially arranged dielectric rings, a terminal ring integrally united to corresponding sides of alternate dielectric rings and having radially inwardly and outwardly extending portions constituting fixed contacts within the envelope and terminal leads outside the envelope, a contact ring integrally united to the corresponding side of an intermediate dielectric ring and having radially inwardly and outwardly extending portions constituting a movable contact within the envelope and a terminal lead outside the envelope, said movable contact portion movable in one direction to engage one of said fixed contacts and movable in the opposite direction to engage another fixed contact.

12. In a vacuumized switch, the combination comprising a metallized dielectric ring, and an annular contact plate constituting an electric conductor extending thereacross having inner and outer peripheral portions, said outer portion being integrally united to said metallized dielectric ring, the remainder of said plate being progressively offset between said outer and inner peripheral portions and to one side of the plane of said outer peripheral portion to form a domed inner peripheral portion lying on one side of a plane coincident with said outer peripheral portion and movable from one side of said plane to the other.

13. In a vacuumized switch having fixed and movable contacts, a flat dielectric ring comprising a main body portion of rectangular radial section and having a reentrant flange integral with the inner periphery of said body portion and interposed between said contacts and said inner periphery.

14. The combination according to claim 13, in which the height of said flange is less than the height of said body portion.

15. The method of displacing a portion of a flat plate to produce a dome therein comprising the steps of arranging a flat plate having a predetermined coefficient of linear expansion on an annular base having a predetermined relatively higher coefficient of linear expansion,

heating the plate and base to a brazing temperature, brazing the plate to the annular base at such temperature, and subsequently cooling the plate and base so brazed whereby the difference in linear contraction of the base exerts a radially inwardly directed compressive force on the plate to effect doming of said plate.

16. The method of integrally uniting and conditioning two spaced and initially parallel plates to effect tensioning of one and compression of the other to form a dome therein comprising the steps of arranging one plate having a predetermined coefficient of linear expansion on one side of an annular base having a predetermined relatively lower coefficient of linear expansion, arranging the other plate having a predetermined coefficient of linear expansion relatively lower than said annular base on the other side of said base from said first mentioned plate, heating the assembly of plates and base so arranged to a brazing temperature, brazing the plates to the base at such temperature, and subsequently cooling the brazed assembly of plates and base to effect contraction of said plates and base by varying amounts whereby one of said plates is tensioned and the other plate is compressed to form a dome therein.

17. The method recited in claim 16, in which said plates are annular metallic membranes and said base comprises a ceramic ring.

18. The method recited in claim 16, wherein said base comprises a ceramic ring metallized on two opposite sides, and a brazing medium is wiped on the sides of said ceramic ring prior to assembly of said plates thereon whereby said plates are hermetically and integrally fused to said ceramic ring by said brazing medium when said brazing temperature is attained.

19. In a vacuumized switch, the combination comprising a metallized dielectric ring, a flat annular conductive contact plate extending thereacross and having an outer peripheral portion integrally united to one side of said ring, a second annular conductive contact plate extending across the opposite side of said dielectric ring and having an outer peripheral portion integrally united thereto and having a domed inner peripheral portion lying on one side of a plane coincident with said opposite side of said ring and movable from one side of said plane to the other to selectively make or break electrical contact between said flat and domed conductive plates.

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