United States Patent [19]

Hundstad

[11] **3,836,740**

[45] **Sept. 17, 1974**

[54] **VACUUM TYPE CIRCUIT INTERRUPTER HAVING IMPROVED CONTACTS**

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[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[21] Appl. No.: **249,990**

[52] **U.S. Cl.** .... **200/144 B,** 200/166 H

[51] **Int. Cl.** **H01h 33/66**

[58] **Field of Search** .... 200/144 B, 166 BH

[56] **References Cited**

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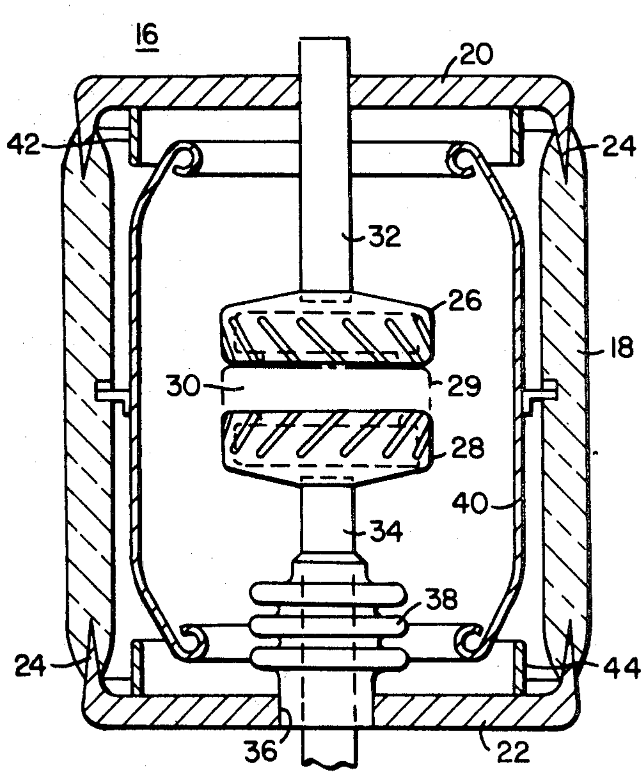
Primary Examiner—Robert S. Macon
Attorney, Agent, or Firm—H. G. Massung

[57] **ABSTRACT**

A vacuum type circuit interrupter comprising cup-shaped electrodes for improved arc movement during circuit interruption. The contact structures of the vacuum-type circuit interrupter are shaped so that when an arc is established between the contacts during circuit interruption the current path through the contacts to the arc is substantially perpendicular to the arc, for improved arc movement. The arc is initiated at the primary contacting surfaces during circuit interruption and is moved rapidly around the contact area thereby preventing the contact area from being grossly eroded.

11 Claims, 13 Drawing Figures



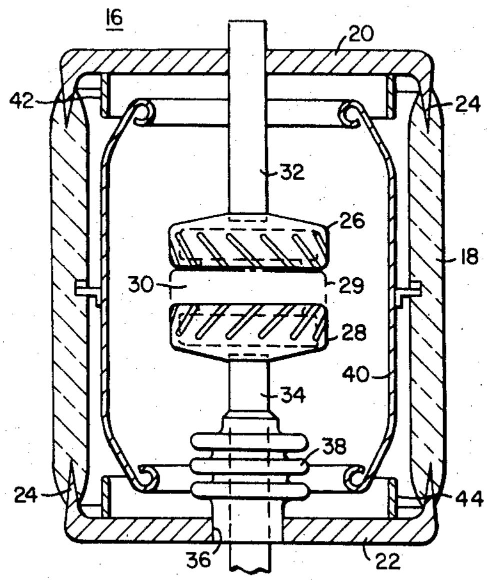


FIG.1

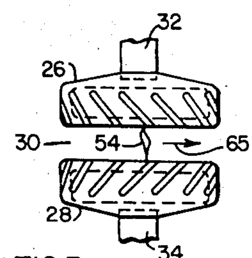


FIG.5

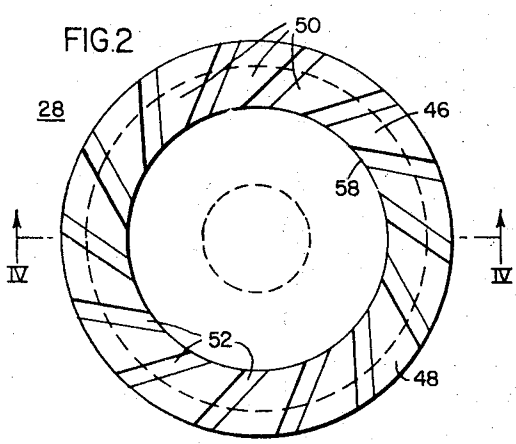


FIG.2

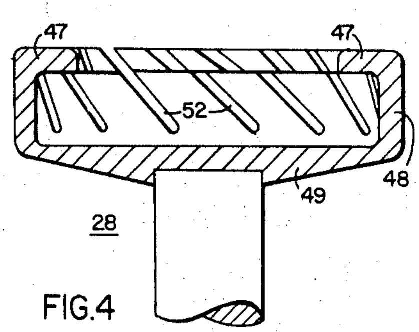


FIG.4

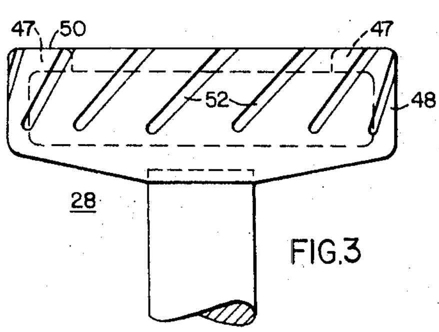


FIG.3

FIG.7

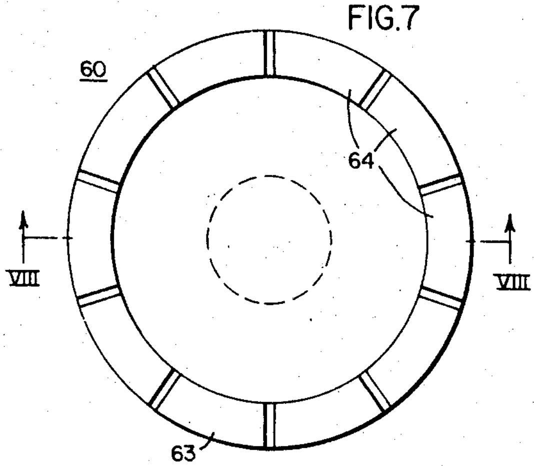
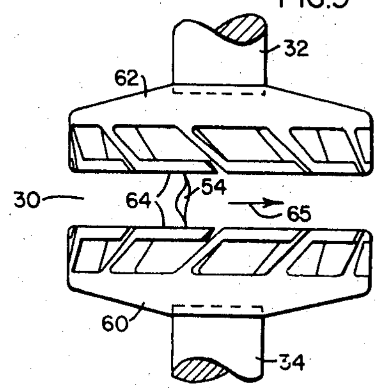


FIG.9



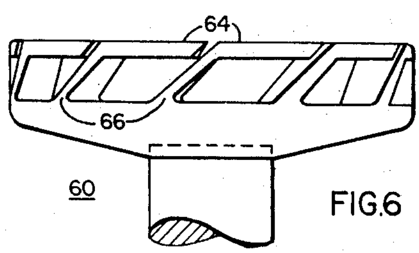


FIG.6

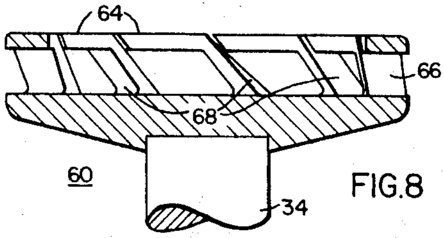


FIG.8

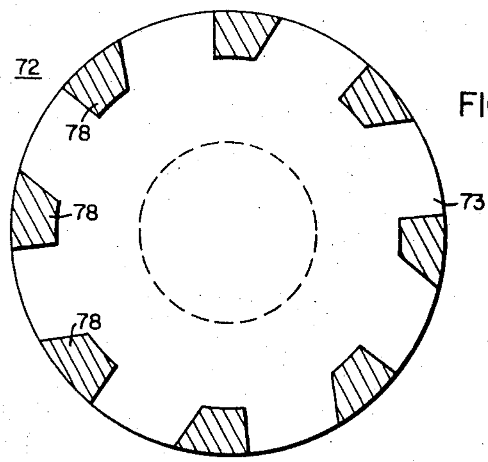


FIG.12

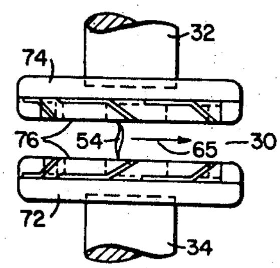


FIG.13

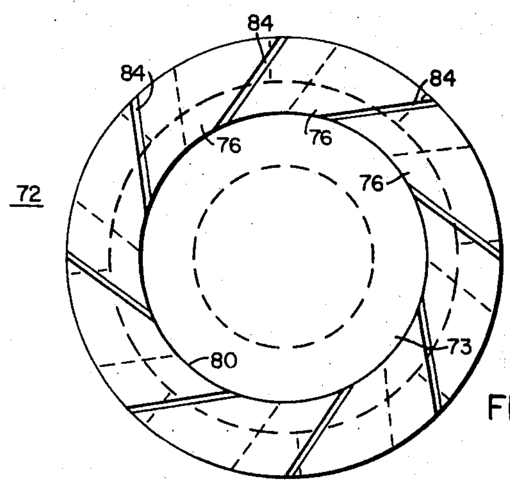


FIG.11

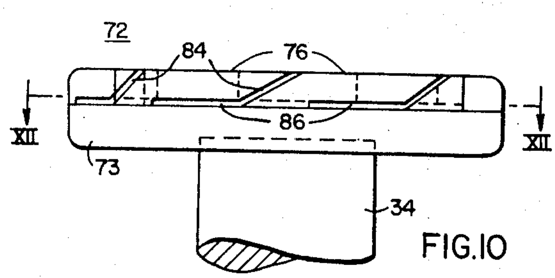


FIG.10

VACUUM TYPE CIRCUIT INTERRUPTER HAVING IMPROVED CONTACTS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to U.S. Patent Office Ser. No. 416,470 filed Nov. 16, 1973, which is a continuation of Ser. No. 249,992, filed May 3, 1973, now abandoned, assigned to the same assignee as the present application.

BACKGROUND OF THE INVENTION

The present invention relates to vacuum-type circuit interrupters and more particularly to contact structures used in such vacuum interrupters. The contacts are constructed to make effective use of the self-induced magnetic field in moving the arc over the contact surface, in a predetermined direction, and thereby distributing the arc energy over the entire contact surface.

In a vacuum interrupter the current normally flows through a pair of contacts located in an evacuated envelope. These contacts are movable relative to each other, and to interrupt current these contacts are moved apart. As the contacts are separated an arc is formed therebetween and current will continue to flow through this arc until the arc is extinguished which on an alternating current circuit will normally occur near the first current zero. The contact surface must support the arc from its initiation at the time of electrode separation until its extinction at approximately current zero. While the arc is being sustained the contacts are subjected to very intense heat. This arc energy causes melting, erosion and general deterioration of the contact surfaces. To minimize deterioration of the contact surfaces it is customary to move the arc around the contact surfaces. Such arc movement tends to minimize the amount of metallic vapors or particles generated by the arc, from the contact surfaces, during circuit interruption. This arc movement is usually accomplished by self-induced magnetic fields as explained in prior art U.S. Pat. No. 3,089,936 issued May 14, 1963 to S. R. Smith, Jr., and U.S. Pat. No. 3,417,216 issued Dec. 17, 1968 to S. R. Smith, Jr.

SUMMARY OF THE INVENTION

According to the present invention a contact configuration for a vacuum-type circuit interrupter is constructed so that the current conducting path in the contact structure is substantially perpendicular to the arc formed during current interruption. The present invention provides an improved vacuum switch contact assembly in which the contacts are shaped so as to provide the maximum self-induced magnetic field, for effective arc movement. If a magnetic field is provided extending across the arc and, a component of this magnetic field extends in a direction perpendicular to the direction of current flow in the arc, the arc will move in a third direction. The direction in which the arc will move is, perpendicular to the current flow in the arc, and perpendicular to the magnetic field component which is at a right angle to current flow in the arc. In a self-induced magnetic field straight parallel rails with current entering and exiting through corresponding ends produces the greatest unbalance in the magnetic field distribution and therefore the greatest magnetic field to drive an arc in a specific predetermined direction. The contact assembly in the present invention is designed so that the current conducting path through the contacts approximate straight parallel rails, for most effective arc movement.

The contacts of the present invention are generally cup-shaped in design and in this respect resemble prior art cup-shaped designs such as U.S. Pat. No. 3,089,936 and U.S. Pat. No. 3,417,216, however, the embodiments here disclosed have significant advantages over prior art contacts. One of the main advantages of the present invention stems from the current carrying path through the contacts, which approximates straight parallel rails for effective arc movement. The embodiments disclosed in the present application make very effective use of the self-induced magnetic field in moving the arc over the contact surface and thereby distributing the arc energy over the entire contact surface.

In one embodiment of the invention a pair of relatively movable cup-shaped contacts are disposed in a vacuum interrupter, the contacts have annular mating ridges which are divided into a plurality of contact surfaces. The contact surfaces are formed so as to approximate parallel rails to produced maximum unbalance in the magnetic field distribution and rapid arc movement. The arc will extend axially of the contacts, and the current path in the contact surfaces will extend substantially perpendicular to the arc, for most of the arc travel. Current flowing in the contact surfaces perpendicular to the arc will produce an intense magnetic field on the one side of the arc tending to move the arc rapidly around the annular contact ridge.

In a second embodiment of the invention, the contacts are cup-shaped with an inward facing lip portion forming an annular ring which is the contact surface. The annular ring is slotted thereby dividing it into a plurality of contacts surfaces. The slots are angled so as to drive the arc in a combined azimuthal and radial inward direction. The angles of the slots cut in the annular ring and the amount by which the lip of the cup extends radially inward are factors which can be used to establish the angular velocity of the arc and its radial position. The arc is thus driven inwardly and rotates rapidly around the inner periphery of the annular contacts surface until it is extinguished. Forcing the arc in an inward direction is a very important feature since it has been found experimentally that current interruption limits are usually reached when the arc interacts with the shield. This embodiment of the present invention tends to confine the arc to the inner electrode space and thereby prevent the arc from interacting with the arc shield. By so confining the arc, the volume of the interrupter can be used more effectively and the radial distance separating the contacts and the main shield can be reduced.

In a third embodiment of the invention multiple contact surfaces are attached at intervals around a disc-shaped electrode, each of these contact surfaces extend inward and circumferential to the disc-shaped electrode. A portion of each contact surface is rigidly attached to the disc-shaped electrode, the portion of each contact surface which is not attached to the disc-shaped electrode, is separated from the disc-shaped electrode by a small amount. Contacts are disposed in the vacuum interrupter facing one another so that when the electrodes are separated the contact surfaces approximate straight parallel rails. When the contacts are separated during circuit interruption an arc is formed therebetween current flowing through the contact surfaces flows perpendicular to the arc to move the arc rapidly inward and around the inner periphery of the annular ring formed by the contact surfaces.

All embodiments of this invention can be constructed to provide small relative motion between the contact surfaces when the contacts are closed so as to increase the number of contact points and thereby reduce contact resistance. The rigidity of the contact surfaces can be controlled by varying wall thickness, the angle of the slots or slot spacing.

All disclosed embodiments of this invention also have the stress concentration feature described in detail in Ser. No. 416,470, for weld breaking.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a sectional view of a vacuum circuit interrupter comprising a contact structure of one embodiment of the invention;

FIG. **2** is an enlarged top view of the contact structure shown in FIG. **1**;

FIG. **3** is a side view of the contact structure shown in FIG. **2**;

FIG. **4** is a sectional view taken along the line IV—IV of FIG. **2**;

FIG. **5** shows a pair of contacts of the type illustrated in FIG. **2** facing each other as they are disposed in a vacuum interrupter;

FIG. **6** is a side view of a contact structure illustrating a second embodiment of the invention;

FIG. **7** is a top view of the contact shown in FIG. **6**;

FIG. **8** is a section view taken along the line VIII—VIII in FIG. **7**;

FIG. **9** shows a pair of contacts of the type shown in FIG. **6** as they are disposed in a vacuum interrupter;

FIG. **10** is a side view of a contact structure illustrating a third embodiment of the invention;

FIG. **11** is a top view of the contact shown in FIG. **10**;

FIG. **12** is a sectional view of the contact shown in FIG. **10** along the line XII—XII; and

FIG. **13** is a side view of a pair of contacts of the type shown in FIG. **10** as they are disposed in a vacuum interrupter.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and to FIG. **1** in particular there is shown a vacuum-type circuit interrupter **16.** The vacuum circuit interrupter **16** comprises a highly evacuated tubular envelope **18** formed from glass or suitable ceramic material and a pair of metallic end caps **20** and **22** closing off the ends of the insulating envelope **18.** Suitable seals **24** are provided between the end caps **20** and **22** and insulating envelope **18** to render the inside of the insulating envelope **18** vacuum tight. The pressure within the envelope **18** under normal operating conditions is lower than 10^{-4} torr to assure that the mean free path for electrons will be longer than the potential breakdown path within the envelope **18.**

Located within the insulating envelope **18** are a pair of relatively movable electrodes or contacts **26** and **28** as shown in FIG. **1** in their open circuit position. When the contacts **26** and **28** are separated there is formed an arcing gap **30** therebetween. The upper contact **26** is a stationary contact secured to a conducting rod **32** by a suitable means, such as welding or brazing. The conducting rod **32** is rigidly joined to the stationary end cap **20** by a suitable means, such as welding or brazing. The lower contact **28** is a movable contact and is joined to a conductive operating rod **34** by a suitable means, such as welding or brazing. The operating rod **34** is suitably mounted for movement along the longitudinal axis of the insulating envelope **18.** The operating rod **34** projects through an opening **36** in the bellows end cap **22** as shown in FIG. **1.** A metal bellows **38** is secured in sealing relationship at its respective opposite ends to the operating rod **34** and to the opening **36** in the bellows end cap **22.** The flexible metallic bellows **38** provides a seal about the operating rod **34** to allow for movement of the operating rod **34** without impairing the vacuum within the envelope **18.**

Coupled to the lower end of the operating rod **34** is a suitable actuating means (not shown) for driving the movable contact **28** upward into engagement with the stationary contact **26** so as to close the interrupter **16.** The closed position of the movable contact **28** is indicated by the dotted line **29.** The actuating means is also capable of returning the movable contact **28** to its open position, during circuit interruption. The circuit opening operation will entail a typical gap length **30,** when the contacts are fully separated, of approximately one-half inch.

When the contacts **26** and **28** are separated during circuit interruption an arc is formed in the arcing gap **30** between the electrodes **26** and **28.** The arc which is formed between the contacts **26** and **28** vaporizes some of the contact material, these vapors and particles are disposed from the arcing gap **30** toward the insulating envelope **18.** The internal insulating surfaces of the insulating envelope **18** are protected from the condensation of these arc generated metallic vapors and particles by means of a tubular metallic shield **40** which is suitably supported on the insulating envelope **18,** and preferably electrically isolated from both ends caps **20** and **22.** This shield **40** acts to intercept and to condense arc generated metallic vapors and particles before they can reach the insulating envelope **18.** To further reduce the chances for vapor or particles reaching the insulating envelope **18,** by bypassing the shield **40,** a pair of end shields **42** and **44** are provided at opposite ends of the main central shield **40.** The speed with which the vapors, generated during arcing, are removed determines the steady state operating condition during arcing, and also the recovery capability of the unit. If the vapor is not quickly removed high voltage transients may cause the arc to reignite, after it has been extinguished, resulting in failure of the interrupter **16.** The arc, interacting with the main shield **40** and melting a hole therethrough, is the cause of many of the failures noted in vacuum interrupters **16.**

Referring now to FIGS. **2, 3** and **4** there is shown a contact structure **28** embodying the teachings of the present invention. Electrode **28** is generally cup-shaped with an inward facing lip portion **47** which forms an annular contact ring **46.** The annular contact ring **46** lies in a plane which is perpendicular to the sides or walls **48** of the cup-shaped electrode **28.** The annular contact ring **46** is divided into a plurality of contact surfaces **50.**

The contact surfaces **50** are formed by cutting slots **52** through the inward facing lip **47** and wall **48** of the cup-shaped electrode **28.** The slots **52** can also be cut completely through the cup-shaped electrode **28.** That is slots **52,** as shown in FIG. **4,** can be extended through the bottom portion **49** of the cup-shaped contact **28.**

The contact **28** is thus made up of multiple contact surfaces **50** which are perpendicular to the walls **48** of the contacts **28.** The slots **52** made in the contact **28** are angled so as to make the contact surface **50** point in a somewhat circumferential or azimuthal direction. Thus, any arc **54,** as shown in FIG. **5,** which is formed when the electrodes **26** and **28** are separated during current intertuption is driven in a combined azimuthal (circumferential) and radial inward direction. This tends to confine the arc **54** to the inner electrode or arcing gap space **30** and thereby prevents the arc **54** from interacting with the arc shield **40.**

The angle of the slots **52** cut in the cup-shaped contact **28** and the amount by which the annular contact ring **46** extends radially inward, are factors which can be used to establish the angular velocity and the radial position of the arc **54.** Note that the slots **52** in contact **26** are opposite those in contact **28** so that when contacts **26** and **28** are disposed in a vacuum interrupter **16,** face-to-face as shown in FIG. **5,** they tend to move the arc in the same direction.

Contacts **26** and **28** are positioned so that the contact surfaces **50** of contacts **26** and **28** face each other and approximate straight parallel rails so as to produce the greatest unbalance in the magnetic field distribution and therefore the greatest magnetic force to drive the arc in a specified predetermined direction. The current path through contact **28** is up the contact wall **48** and through one of the contact surfaces **50** to the arc **54,** so that the current path in the contact surface **50** is at substantially a right angle to the longitudinal axis of the arc **54.** During circuit interruption when an arc is formed between contacts **26** and **28** the arc is driven inward and rotates rapidly around the inner periphery **58** of the annular ring **46** until the arc **54** is extinguished, which occurs on an alternating current circuit at approximately the first current zero.

Referring now to FIGS. **6, 7, 8** and **9** there is shown a contact structure **60** illustrating a second embodiment of the invention. The contact **60** is generally cup-shaped with an annular contact surface **63** which is divided into multiple contact surfaces **64.** The walls **66** of the cup-shaped contact **60** are formed so that current flowing to the arc **54** during circuit interruption must flow through the contact surfaces **64** perpendicular to the axis of the arc **54.** Current flow to the contact surfaces **64** is through a restricted portion **68** so that current flowing in the contact surfaces **64** flows at substantially a right angle to the arc **54.** As shown in FIG. **9** contact **62** is a mirror image of contact **60.** The contacts **60** and **62** are disposed in a vacuum interrupter **16** so that the contact surfaces **64** approximate parallel rails, and during circuit interruption the arc **54** is driven rapidly around the annular contact surface **63,** in the direction indicated by arrow **65,** until it is extinguished. Current to the arc **54** during the major portion of the arc travel must flow through the contact surfaces **64** at substantially a right angle to the axis of the arc **54** to produce a greater unbalance in a magnetic field distribution and therefore a greater magnetic field to drive the arc in a more predetermined or controlled direction than in the prior arc contact structures.

Referring now to FIGS. **10, 11, 12** and **13** there is shown a third embodiment of the invention on a contact structure **72.** Contact **72** has a disc-shaped portion **73** with contact surfaces **76** attached at points **78** around the outer perimeter of the disc-shaped portion **73.** Contact surfaces **76** can be made integral with the disc-shaped portion **73,** or contact portion **76** can be attached to the disc-shaped portion **73** by a suitable means, such as welding or brazing. The contact surfaces **76** are attached to the disc-shaped surface **73** at points **78,** and at other areas are separated from the surface **73** by a slight gap. The contact surfaces **76** point in a generally radially inward and circumferential direction.

Contact **74** as shown in FIG. **13** is a mirror image of the contact **72** through a plane perpendicular to the longitudinal axis of the operating rod **34** and the stationary rod **32** and located midway between contacts **72** and **74.** An arc **54** forms during circuit interruption and is driven rapidly inward and around the inner edge **80** of the contact surfaces **76.** The contact surface **76** are in a plane which is parallel to the top of the disc-shaped portion **73.** As shown in FIG. **13** the contact surfaces **76** of contacts **72** and **74** face each other so as to approximate straight parallel rails. Current flowing through the contact surfaces **76** to the arc **54** flows at right angles to the arc **54** so as to produce the greatest unbalance in the self-induced magnetic field distribution and therefore to move the arc most efficiently in a specified direction. The arc **54** moves around the contacts **72** and **74** in the direction indicated by arrow **65.** This construction of contact **72** drives the arc in a combined azimuthal (circumferential) and radial inward direction. The arc **54** is generally confined to the inner electrode or arcing space **30** and is thereby prevented from interacting with the arc shield **40.** This is very important since it has been determined experimentally that current interruption limits are reached when the arc **54** interacts with the shield **40.** In most cases a hole is melted in the arc shield **40** and the interrupter **16** fails. By a partial confinement as suggested by this embodiment the volume of the interrupter can be used more effectively. The radial distance separating the contacts **72** and **74** and the arc shield **40** can be reduced. In this embodiment of the invention the contact surfaces **76** are separated from each other by slots **84,** and are separated from the disc-shaped portion **73** of the electrode **72** by gaps **86.** The configuration of these separations **84** and **86** and the amount by which the contact surfaces **76** project toward the center of the disc-shaped portion **73,** beyond the attachment point **78,** are factors which can be used in establishing the angular velocity of the arc **54** and its radial inward position.

The contact structures, disclosed in this invention have several advantages, for instance the contact surfaces **50, 64** and **76** can be supported for slight relative motion so as to increase the number of contact points and thereby reduce contact resistance when the interrupter **16** is closed. Another advantage of contacts **28** and **72** is that the arc **54** is forced radially inward and is prevented from interacting with the arc shield **40.** All contacts configurations **28, 60** and **72** effectively employ stress concentration to aid in breaking any welds which might occur between the contacts. Yet another important advantage of all these designs is that the current through the contacts **28, 60** and **72** and the arc **54** must travel through the contact surfaces **50, 64** and **76,** respectively, perpendicular to the axis of the arc **54** and this produces a greater unbalance in the self-induced magnetic field distribution and therefore a greater magnetic field to drive the arc in a specified direction than prior art contacts.

Since numerous changes may be made in the above-described apparatus different embodiments of the invention may be made without departing from the spirit and scope thereof. It is intended that all the matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A vacuum interrupter having a first contact and a second contact being relatively movable with respect to the first contact between a closed position in engagement with the first contact and an open position separated from the first contact to form an arcing gap therebetween across which an arc is formed during circuit interruption wherein each contact comprises:

a flat circular base portion having a solid disc shape;

an annular contact and arcing portion having a relatively thin cross-sectional area and being divided into a plurality of contact and arcing surfaces;

contact support means for supporting each contact and arcing surface from one end only and for positioning said annular contact and arcing portion slightly above said disc-shaped portion by a distance less than the thickness of said annular contact and arcing portion; and

each of said contact and arcing surfaces connected to said flat circular base portion near the outer periphery and extending from the connection in a radially inward and circumferential direction so that the arc formed during circuit interruption is moved radially inward and rotated around the inner diameter of said annular contact and arcing portion.

2. A vacuum interrupter as claimed in claim **1** wherein:

said plurality of contact and arcing surfaces of said annular contact and arcing portion lie in a common plane so that when said vacuum circuit interrupter is closed with the second contact in engagement with the first contact the entire annular contact and arcing portion of the first contact engages the entire annular contact and arcing portion of the second contact and when said vacuum interrupter is in the open position with the first contact separated from the second contact an arcing gap having a uniform length is formed therebetween.

3. A vacuum interrupter as claimed in claim **2** wherein most of the contact support means for each contact and arcing surface is positioned beneath the preceding contact and arcing surface whereby the current flow through the contact and arcing surfaces during arcing must be substantially parallel to said flat circular base portion and perpendicular to any arc formed during circuit interruption.

4. A vacuum interrupter as claimed in claim **3** wherein:

each of said contact support means is joined to said flat circular base portion in a trapezoidal shaped figuration with two sides of the trapezoid extending generally radially inward a distance from the outer periphery of said flat circular base portion less than the radially inward spacing of said annular contact and arcing portion; and

with the outer side of the trapezoid running parallel and in alignment with the outer periphery of said flat circular base portion.

5. A vacuum interrupter as claimed in claim **2** wherein said annular contact and arcing portion has an inner diameter which is greater than the radius of said flat circular base portion.

6. A vacuum interrupter as claimed in claim **2** wherein said annular contact and arcing portions have an outer diameter which is approximately equal to the outer diameter of said flat circular base portion.

7. A vacuum interrupter as claimed in claim **3** wherein said contact support means for supporting each contact and arcing surface from one end only is resilient to allow each of said contact and arcing surfaces to flex slightly and provide that complete contact is made at each contact and arcing surface when the first contact and second contact are in engagement.

8. A vacuum interrupter as claimed in claim **4** wherein, the contact areas where each of said contact support means joins said flat circular base portion define an annular ring with the contact support means joined to the flat circular base portion at discreet intervals on the defined annular ring and the area of the annular ring covered by said contact support means joining to said flat circular base portion is substantially less than the area defined by the annular ring.

9. A vacuum interrupter as claimed in claim **1** wherein said contact support means supports said contact and arcing portion above said disc-shaped portion by a distance less than the length of the arcing gap.

10. A vacuum interrupter as claimed in claim **1** wherein said contact support means supports said contact and arcing portion above said disc-shaped portion by a distance less than one-fourth of an inch.

11. A vacuum interrupter as claimed in claim **1** wherein said contact support means supports said contact and arcing portion above said disc-shaped portion by a distance less than the radius of said base portion.

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