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[54] **VACUUM INTERRUPTER FOR HIGH VOLTAGE APPLICATION**

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[52] **U.S. Cl.** ..... **200/144 B**
[51] **Int. Cl.** **H01h 33/66**
[58] **Field of Search** ..... 200/144 B

[56] **References Cited**

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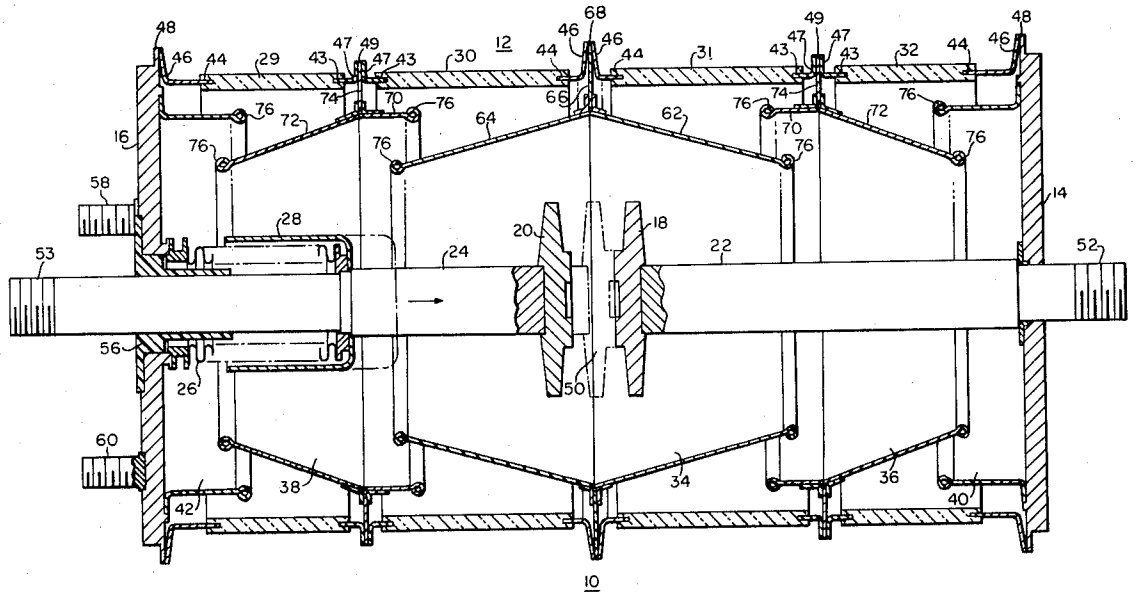
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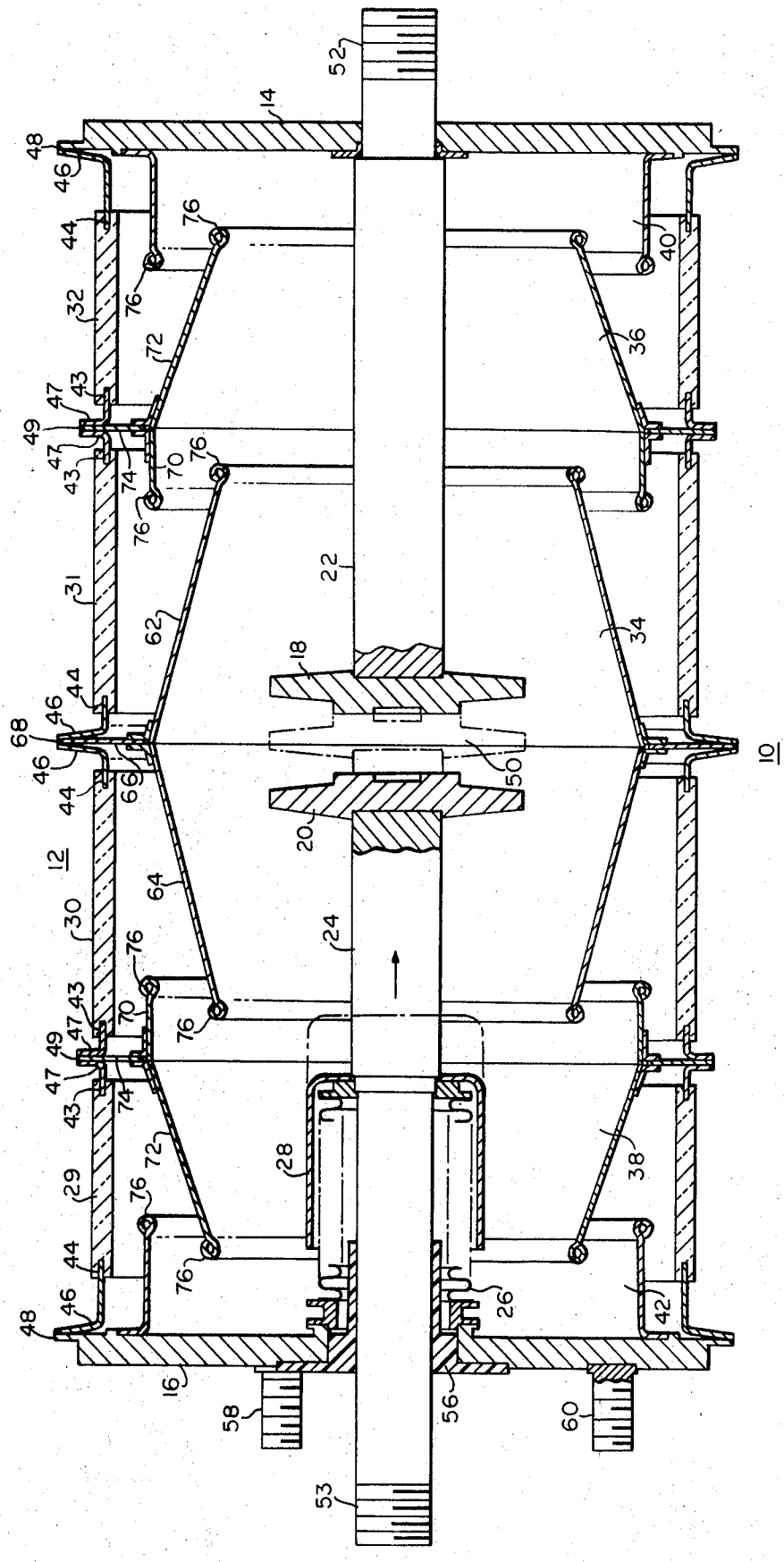
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[57] **ABSTRACT**

An improved shielding arrangement in a vacuum-type circuit interrupter for increasing the basic insulation level (BIL) and preventing the accumulation of a metallic coating on the internal insulating surfaces which can cause failure of the interrupter.

5 Claims, 1 Drawing Figure




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VACUUM INTERRUPTER FOR HIGH VOLTAGE APPLICATION

BACKGROUND OF THE INVENTION

This invention relates to a vacuum-type circuit interrupter and more particularly to an improved shielding arrangement in the interrupter.

In a usual vacuum-type circuit interrupter an envelope or housing fabricated from a suitable insulating material, such as glass, ceramic, or the like, forms a vacuum chamber in which a pair of separable contacts or electrodes are disposed. In the closed position direct electrically conducting contact is made between the electrodes of the interrupter and a continuous current path is established through the interrupter. In the open circuit position the electrodes are spaced apart and no current flows therebetween. During operation, current interruption is initiated by separating the electrodes. When the electrodes separate an arc is formed across the annular gap. The arc vaporizes a portion of the metallic electrode material and these particles become ionized to help sustain the arc, through which current flows until a natural current zero is reached. After the current zero point has been reached, the recovery voltage transient begins building up between the separated electrodes. If the dielectric strength of the gap is sufficiently strong to withstand the recovery voltage transient, breakdown will not occur, the arc will not reignite and circuit interruption will be complete. If the internal insulating surfaces of the interrupter are not protected, the metallic vapor formed during arcing will condense on the internal surfaces and form a metallic coating. After a number of interruptions, the metallic coating will form a shorting path and cause the interrupter to fail. To protect the insulating surfaces of the vacuum interrupter it is customary to provide metal shielding, located between the insulating surfaces and the arc formed during interruption. This type of construction is exemplified by U.S. Pat. No. 3,185,800. Most of the metallic vapor then condenses on the shielding surfaces before reaching the insulating surfaces of the vacuum interrupter. The shielding thus collects any particles, and condenses the metal vapor, given off from the electrodes during the arcing, protecting the insulating envelope or housing of the interrupter.

During operation, it is desirable that, any arc generated during interruption should be confined to the electrodes and not come into contact with the metal shield. Due to the confined space in the vacuum interrupter, there is a possibility that, the arc will strike the shielding. If the arc contacts the shielding, it is desirable that the arc which does occur be confined to the inside of the shielding surface facing away from the insulating envelope. On low pressure arcs formed between interrupter electrodes, designed in such a way that asymmetries will occur in the self magnetic field produced by the current, it has been observed that the cathode spots move in the retrograde direction, while the remainder of the plasma appears to to obey Ampere's Law. It has been found that electrodes designed, according to Ampere's Law, to drive the arc in a prescribed direction are not always effective. Because low pressure arcs in self-magnetic fields exhibit the phenomena that cathode spots travel in the retrograde direction, geometric shaping of the shielding ends, such as with curls, to control the movement of the arc are not effective. If cathode spots travel to the outside of the shield, and these surfaces face the insulating surfaces of the interrupter, metal vapor sputtered from the cathode spots will be deposited on the insulating envelope and eventual interrupter failure will result.

In a commercially successful vacuum interrupter a high basic-impulse insulating level (BIL) is necessary. A non-uniform voltage distribution around the external insulating envelope adversely affects the withstand voltage of the interrupter and lowers the BIL. In the prior art of vacuum interrupters, the voltage distribution around the external envelope is non-uniform. One of the causes of this non-uniform electric field is the lack of symmetry in the shielding arrangement. This objection to the prior art structures is eliminated by the invention provided herein.

SUMMARY OF THE INVENTION

A vacuum interrupter comprising an insulating envelope generally tubular in shape, two metal end plates mounted on opposite ends of the insulating envelope, a stationary contact assembly, a movable contact assembly, with the contact movable along the longitudinal axis of the insulating envelope into and out of engaement with the stationary contact, and a multiple electrically isolated shielding arrangement. The insulating envelope is evacuated to a pressure of 10^{-8} Torr or lower. The multiple shielding arrangement comprises three shields wich are electrically isolated or floating from each other, from the electrodes and from ground. The disclosed design of multiple floating shields is used to improve the voltage distribution across the interrupter, when electrodes are separated and a BIL voltage transient is applied to the vacuum switch. The spacing between the shields and the number of shields is determined from a field map of the internal and external voltages and voltage gradients when a 200 KV potential is placed across the tube with electrodes separated. Since the geometry of the shields, electrodes and other metallic parts of the unit are quite complex a computerized field map program which calculates and prints out the voltage gradient as well as the voltage is employed. The uniform voltage distribution across the outside of the interrupter envelope is attributed to the proper selection of intershield capacitance.

In the instant invention, when the vacuum switch is in the open position, the electrodes are separated and an annular arcing gap is present therebetween. Surrounding this annular gap is the main floating shield which is barrel shaped or more specifically, shaped like two frustums of right circular hollow cones joined base to base. The longitudinal axis of the barrel shaped shield and the longitudinal axis of the insulating envelope coincide. The ends of the barrel shaped shield extend inside hollow cylindrical portions of two end shields. The two end shields, which are identical in construction, are shaped like a frustum of a right circular hollow cone with a hollow cylindrical, or tubular, portion joined to the base of the cone. The longitudinal axis of the end shields and the longitudinal axis of the tubular insulating envelope coincides. The three shields are electrically isolated from each other and from the electrodes. Note that the floating shield arrangement is symmetrical, about a plane through the annular arcing gap and perpendicular to the longitudinal axis of the insulating envelope, for a uniform voltage distribution.

A vacuum interrupter constructed in accordance with the present invention can have a greatly improved BIL. For example, under tests the BIL of an experimental 34 KV vacuum interrupter was raised from 140 KV to 186 KV, by constructing the shielding arrangement in accordance with the teachings of the present invention, without changing the physical dimensions of the insulating envleope.

Another advantage of the present invention is that by having the hollow cylindrical portion of the end shields overlap the end of the main center shield there can be no cathode spots tracking on the outer surfaces of the floating shields which face the insulating envelope. The absence of cathode spot tracking on these surfaces has been verified experimentally. If the cathode spot tracking were present, as would be possible if the floating end shields were inside the end of the center shield, metal vapors sputtered from the surfaces of the end shields could be directly deposited on the insulating envelope.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a partial view, in side elevation, of a vacuum interrupter embodying the principle features of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 there is shown a vacuum type circuit interrupter **10.** The vacuum interrupter **10** comprises a tubular insulating envelope or housing **12,** a stationary end cap **14,** a bellows end cap **16,** a stationary contact **18** and a movable contact **20.** The stationary end cap **14** and the bellows end cap **16** are located at opposite ends of the tubular insulating envelope or housing **12.**

The insulating envelope or housing **12** comprises four tubular insulating portions **29, 30, 31** and **32** made from a suitable insulating material, such as glass, ceramic, or the like. Attached to one end of the tubular insulating portions **29, 30, 31** and **32,** so as to form a vacuum tight seal **44,** are flanged metal tubes **46** and attached to the other end, so as to form a vacuum tight seal **43,** are flanged metal tubes **47.** These flanged metal tubes **46** amd **47** have a coefficient of thermal expansion which is approximately equal to the coefficient of thermal expansion of the insulating tubes **29, 30, 31** and **32.** The flanged metal tubes **46** and **47** are constructed from a suitable material, such as Kovar, which is a trademark of the Westinghouse Electric Corporation, consisting of 25–34 percent nickel, 4–17 percent cobalt, less than 1 percent manganese, and the balance iron. For more detailed information on Kovar consult U.S. Pat. Nos. 2,217,422; 1,872,354; and 1,942,261. The bellows end cap **16** and the stationary end cap **14** are joined to two of these flanged metal tubes **46,** which are attached to the insulating tubes **29** and **32,** by suitable means, such as welding or brazing, to form a vacuum tight seal **48.**

Disposed within the tubular insulating envelope **12** is the stationary contact **18** and the movable contact **20.** The stationary contact **18** is attached to a stationary contact rod **22** by suitable means, such as brazing. The movable contact **20** is attached to a movable contact rod **24** by a suitable means, such as brazing. FIG. **1** shows the movable contact **20** in the open position. When the movable contact **20** is in the closed position, it is in contact with the stationary contact **18** and a continous current path extends from the movable contact rod **24,** through the movable contact **20,** through the stationary contact **18,** and through the stationary contact rod **22.** The movable contact **20** is movable along the longitudinal axis of the insulating housing **12** so that when the vacuum switch **10** is in the open circuit position there is an annular arcing gap **50** between the contacts **18** and **20.** During circuit interruption, as the movable contact **20** moves from the closed to the open position, an arc is formed between the contacts **18** and **20** across the annular space **50.** On an alternating current circuit, this arc is normally extinguished at the first current zero of the alternating current wave. Very quickly, after the arc is extinguished, the high dielectric strength of the vacuum is recovered and reignition is prevented thus completing interruption.

The stationary contact rod **22** is joined to the stationary end cap **14** by a suitable means, such as brazing or welding. The end **52** of the stationary contact rod **22,** which extends through the stationary end cap **14,** may be threaded to facilitate attachment of a terminal. A bellows **26** is attached to the movable contact rod **24** and to the bellows end cap **16** so as to permit movement of the contact rod **24** along its longitudinal axis without affecting the vacuum inside the envelope **12.** A bushing **56** of a material having a low coefficient of friction such as polytetrafluoroethylene, which is sold under the trade mark "Teflon," is disposed in the bellows end cap **16** so that the movable contact rod **24** passes therethrough. This bushing **56** facilitates opening and closing of the movable contacts **20.** Attached to the movable contact rod **24** and surrounding most of the bellows **26** is a cup-shaped metal shield **28.** The bellows shield **28** protects the bellows **26** from bombardment by particles expelled during arc interruption. Attached to the bellows end cap **16** are two threaded studs **58** and **60** which are used for mounting the vacuum switch **10.** The end **53** of the movable contact rod **24** is threaded for attachment of an operating mechanism (not shown) and an end terminal connection (not shown).

During circuit interruption the movable contact **20** separates from the stationary contact **18** and an arc develops across the annular arcing gap **50.** The arc that is formed vaporizes some of the material from the contacts **18** and **20** and the resulting metallic vapors are ejected radially outward from the arcing gap **50,** in a straight line.

Three electrically isolated or floating shields **34, 36** and **38** and two tubular end shields **40** and **42,** which are attached to the end caps **14** and **16,** respectively, are are provided to collect the metallic vapors that are produced by the evaporation of material from the contacts **18** and **20,** which results from arching during circuit interruption. These metallic shields **34, 36, 38, 40** and **42** in conjunction with the metallic end caps **14** and **16** and the bellows shield **28** intercepts substantially all of the particles expelled from the arcing contacts, and quickly condense any metallic vapor generated, thus protecting the insulating housing **12** from these metallic vapors. The speed with which the vapor is removed effects operation of the vacuum interrupter **10.** If the metallic vapor is not quickly removed high

voltage transients may cause the arc to reignite between the contacts **18** and **20** resulting in failure of the unit **10.**

The main barrel shaped center shield **34** is disposed within the insulating envelope **12,** around the annular arcing gap **50,** and is electrically isolated from other shielding members **36, 38, 40,** and **42** from electrodes **18** and **20,** and from ground. The main shield **34** is formed by electron beam welding or vacuum brazing together two frustums of right circular hollow cones **62** and **64** at their base. For support of the barrel shaped shield **34** an annular metallic disc **66** is attached to the shield **34** by suitable means, at the point where the frustums of the right circular cones **62** and **64** are joined base to base. The annular disc **66** is then attached to the two flanged metal tubes **46** which are joined to the tubular portions **30** and **31** of the insulating envelope or housing **12** so as to form a vacuum tight seal **68.** The main barrel shaped shield **34** is thus disposed within the insulating envelope **12** so that the longitudinal axis of the barrel shaped shield **34** and the longitudinal axis of the insulating envelope **12** coincide. The barrel shaped shield **34** is formed from a suitable material, such as copper, nickel or stainless steel.

The first stationary end shield **36** and the second stationay end shield **38** which are identical in construction are disposed within the insulating envelope **12.** These end shields **36** and **38** are electrically isolated from each other, from all other shielding, from the electrodes **18** and **20** and from ground. Both shields **36** and **38** comprise a tubular portion **70** which is joined to the base of a portion **72,** which is shaped like the frustum of a right circular hollow cone, by a suitable means, such as electron beam welding. An annular metal disc **74** is joined to shields **36** and **38** at the point where portions **70** and **72** are joined together. The annular metal disc **74,** which is attached to the second end shield **38,** is then attached to the two flanged metal tubes **47,** which are joined to tubular portions **29** and **30,** so as to suspend the second electrically floating end shield **38** within the insulating envelope **12.** The annular metal disc **74,** which is attached to the first end shield **36,** is then attached to the two flanged metal tubes **47,** which are joined to tubular portions **31** and **32,** so as to suspend the first stationary end shield **36** within the insulating envelope **12.** Vacuum tight seals **49** are formed where the annular metal discs **74** are joined to the flanged metal tubes **47.** The end shields **36** and **38** are disposed in the insulating envelope **12** so that the longitudinal axis of the end shields **36** and **38** coincide with the longitudinal axis of the tubular insulating envelope **12.** The end shields **36** and **38** are constructed of a suitable material such as copper, nickel, or stainless steel.

The third end shield **40,** which has a flanged portion, is attached to the stationary end cap **14.** The third end cap shield **40** is at the same electrical potential as the stationary contact **18.** The fourth end shield **42,** which has a flanged portion, is attached to the bellows end cap **16.** The fourth end cap shield **42** is at the same electrical potential as the movable contact **20.** The end shields **40** and **42** are formed from a suitable material such as copper, nickel or stainless steel. The floating shields **34, 36** and **38** are symmetrical about a plane, through the annular arcing gap **50** and perpendicular to the longitudinal axis of the insulating envelope **12,** for a uniform voltage distribution. To reduce high electrical stress concentration at the end of the shields **34, 36** and **38, 40** and **42,** the free shield ends are curled into a generally tubular shaped ring **76.** A substantially ring shaped tube **76** is thus formed at the free ends of the shields **34, 36, 38, 40** and **42.** By thus shaping the ends of the shields, high electrical stress at the shield ends are prevented. Note that joining of the metallic shielding parts is accomplished by electron beam welding or vacuum brazing, these methods were selected because with them there is less probability of introducing gas into the shield.

The design of the floating shields **34, 36, 38** are such as to improve the voltage distribution across the interrupter **10** when the movable contact **20** is separated from the stationary contact **18** and a BIL voltage transient is applied to the interrupter **10.** Electric field plots show that the external and internal voltage distribution of the disclosed interrupter **10** is more uniform than the voltage distribution of prior art interrupters. The uniform electric field distribution in the present invention, which is due to the proper selection of intershield capacitance, permits higher BIL levels for the same physical size interrutper **10.**

The ends of the barrel shaped center shield **34** project inside the circular portions **70** of the floating end shields **36** and **38.** By having the circular portions **70** of the end shields **36** and **38** overlap the ends of the barrel shaped shields **34** no arc trails can proceed to the outside surfaces of the shields which are exposed to the insulating housing **12.** This means that no metal vapor can be sputtered from these surfaces and directly deposited on the inside walls of the insulating envelope **12.** If the end shields **36** and **38** were disposed within the end of the barrel shield **34** and the shields **34, 36** and **38** became involved in arcing then cathode spots could burn over the outer surface and metal vapor sputtered from the cathode spots on these surfaces could be directly deposited on the insulating envelope **12.** The present invention prevents this possibility of direct deposit of metallic vapor or particles on the inside walls of the envelope **12.**

The apparatus embodying the teachings of this invention has several advantages. For example, due to the multiple floating shields geometry taught in the invention, voltage gradients between the shields **34, 36, 38, 40** and **42** are reduced both during arcing and for BIL requirements. Another advantage of this multiple floating shield arrangement is that the arc trails cannot proceed to the outside surfaces of the shields **34, 36, 38, 40** and **42,** which are exposed to the insulating envelope **12,** therefore the possibility of depositing metal vapor on the inside walls of the insulating envelope **12** or causing other damage to the insulation is minimized. Another advantage of the disclosed multiple floating shield arrangement is that the voltage distribution across the interrupter **10** is uniform and a higher BIL can be attained.

Since numerous changes may be made in the above described apparatus and 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 drawing shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A vacuum type circuit interrupter comprising an evacuated tubular insulating housing;

a stationary electric contact rigidly positioned with respect to the insulating housing, said stationary contact being radially centered in said housing;

a movable electric contact, movable along the longitudinal axis of said insulating housing between a closed position in contact with said stationary contact and an open position displaced from said stationary contact to establish an arcing gap therebetween;

a central circular hollow metallic shield, disposed internally of said tubular housing, surrounding the arcing gap and said stationary contact and said movable contact, said central circular hollow metallic shield is spaced radially outward from the outer periphery of the arcing gap and is electrically isolated from said stationary contact and from said movable contact;

a first end circular metallic shield disposed within the end of said tubular insulating housing and surrounding one end of said central circular hollow shield, said first end shield being electrically isolated from said stationary contact from said movable contact and from said central shield;

a second end metallic shield disposed within the end of said tubular insulating housing opposite the end within which said first end metallic shield is disposéd and surroundng one end of said central circular shield, said second end metallic shield being electrically isolated from said stationary contact from said movable contact from said central circular shield, and from said first end metallic shield; and including, a third end shield which is electrically connected to said stationary contact and surrounds the ends of said first end shield which faces the end of said insulating housing in which the first stationary end shield is disposed; a fourth end shield which is electrically connected to said movable contact and surrounding the end of said second end shield which faces the end of said insulating housing in which the second end shield is disposed.

2. The combination as claimed in claim **1** wherein said central circular shield is shaped like two frustums of right circular hollow cones joined base to base, said central circular shield being spaced a greater distance from the arcing gap than said movable contact is separated from said stationary contact when in the open position so that an arc formed during circuit interruption does not normally intereact with said central circular shield, and said central shield being positioned so that its longitudinal axis coincides with the longitudinal axis of the insulating housing and the center of gravity of said central shield is located within the annular arcing gap formed between said stationary contact and said movable contact, when said movable contact is in the open position.

3. The combination as claimed in claim **1** wherein said first end circular metallic shield and said second end metallic shield are identical in shape and construction.

4. The combination as claimed in claim **3** wherein said first end circular metallic shield and said second end metallic shield comprise frustums of a right circular hollow metallic conical portion which have joined to their bases tubular portions, said tubular portion of said first end shield surrounds one end of said circular central shield and the smaller diameter opening in the frustum of the right circular conical portion of said first stationary end shield faces the end of said insulating housing nearest said stationary contact, said tubular portion of said second end metallic shield surrounds another end of said circular central shield and the smaller diameter opening in the frustum of the right circular conical portion faces the end of said insulating housing nearest said movable contact.

5. The combination as claimed in claim **1** wherein the longitudinal axis of said insulating housing coincides with the longitudinal axis of said central circular shield, the longitudinal axis of said first end shield coincides with the longitudinal axis of said insulating housing, the longitudinal axis of said second end shield coincides with the longitudinal axis of the insulating housing, and said central circular hollow shield and said first end shield and said second end shield all being symmetrical about a plane through the arcing gap and perpendicular to the longitudinal axis of the insulating housing whereby a uniform voltage distribution over the outer surface of said insulating housing is present when a potential is applied to the vacuum interrupter and the movable contact is in the open circuit position.

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