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VACUUM TYPE CIRCUIT INTERRUPTER

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Fig. 1.

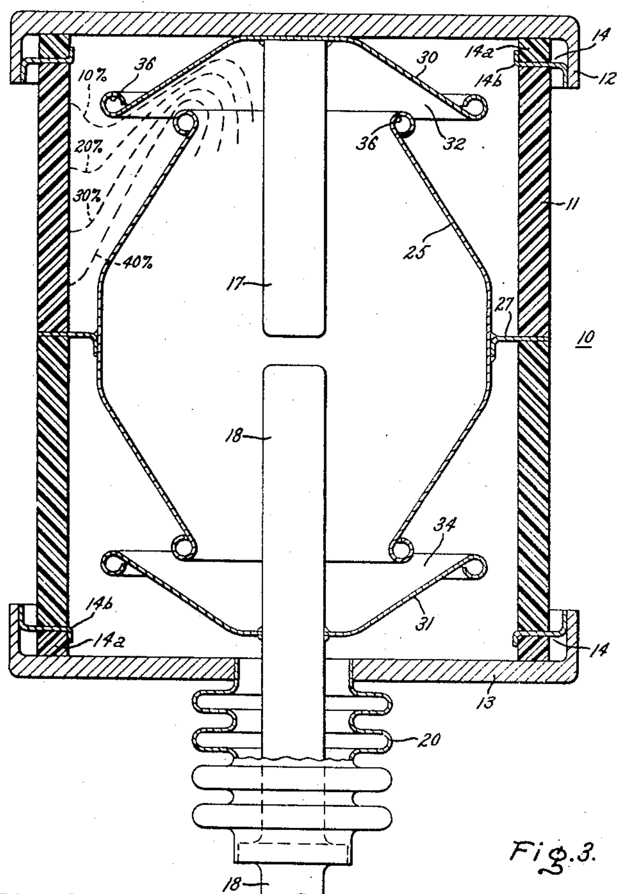


Fig. 2.

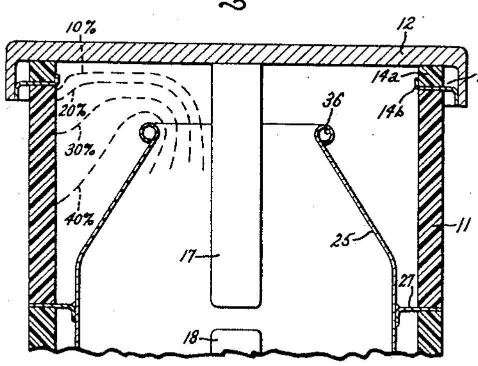
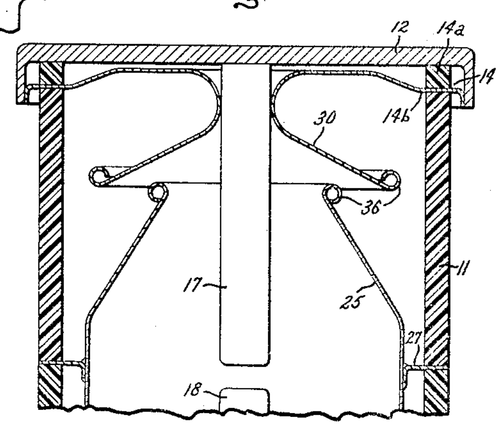


Fig. 3.



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2,892,912

VACUUM TYPE CIRCUIT INTERRUPTER

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10 Claims. (Cl. 200—144)

This invention relates to a vacuum-type circuit interrupter and, more particularly, to an improved shielding arrangement for protecting the insulation of the interrupter against the build-up of metallic coatings thereon and for effecting an optimum distribution of voltage stresses along the insulation of the interrupter.

In vacuum circuit interrupters, the metallic vapors which are produced by arcing tend to condense on the insulating surfaces of the interrupter and, hence, to form metallic coatings which impair the insulating properties of such surfaces. For protecting these insulating surfaces against such metal-deposition, it has been found highly desirable to utilize an electrically-floating shield which is isolated from the electrodes of the interrupter by means of a pair of series-related vacuum gaps. A shield of this type is disclosed and claimed in application S.N. 630,247, filed in the name of D. W. Crouch and assigned to the assignee of the present invention.

An object of the present invention is to form these series-related vacuum gaps in such a manner that the metallic particles liberated by arcing cannot readily pass therethrough to coat the adjacent insulation.

Another object is to form the gaps by relying upon a pair of end-shields which coact with the floating shield in such a manner as to transfer electric stresses from relatively vulnerable parts of the interrrupter to less vulnerable parts thereof.

Still another object is to assure that no arcing takes place from the usual conductive end-caps of the interrupter.

In carrying out our invention in one form, the arcing gap between the electrodes of a vacuum circuit interrupter is surrounded by a generally-tubular metallic shield which is electrically isolated from both electrodes. Coacting with this isolated shield are a pair of generally-tubular end-shields which are respectively electrically-connected to the electrodes. These end shields extend into proximity with the isolated shield so that a pair of series-related vacuum gaps are provided at opposite ends of the isolated shield. This entire structure is housed within an insulating casing, and the gaps are so disposed that they present a tortuous path for any metallic particles emitted from the arcing gap and travelling toward the insulating surfaces of the casing.

For a better understanding of our invention, reference may be had to the following specification taken in connection with the accompanying drawings, wherein:

Fig. 1 is a vacuum-type circuit interrupter embodying our invention.

Fig. 2 illustrates certain electrical relationships which would be present in an interrupter similar to that of Fig. 1 but with certains parts omitted.

Fig. 3 is a modified form of vacuum-type interrupter embodying our invention.

Referring now to the interrupter of Fig. 1, there is shown a highly-evacuated envelope **10** comprising a casing **11** of insulating material, such as a suitable ceramic, and a pair of metallic end caps **12** and **13** closing off

the ends of the casing. Suitable seals **14** are provided between the end caps and the casing to render the envelope **10** vacuum-tight. Preferably, each of these seals **14** comprises a ceramic annulus **14***a* located at one end of the insulating casing **11** and an annular metallic disc **14***b* sealingly interposed between the casing and the annulus. A vacuum-tight joint is provided between the outer periphery of the metallic disc **14***b* and the adjacent end cap, preferably, by means of a suitable brazing or welding process.

Located within the envelope **10** are a pair of separable electrodes, or rod contacts, **17** and **18** shown in the open-circuit position. The electrode **17** is a stationary electrode suitably united to the upper end cap **12**, whereas the electrode **18** is a movable electrode suitably mounted for vertical movement and projecting through an opening in the lower end cap **13**. A flexible metallic bellows **20** interposed between the end cap **13** and the movable electrode **18** provides a seal about the movable electrode and allows for vertical movement thereof without impairing the vacuum inside the interrupter. As shown in the drawing, the bellows **20** is sealingly secured at its respective opposite ends to the electrode **18** and the end cap **13**.

Coupled to the lower end of the movable electrode **18**, we provide suitable actuating means (not shown) which is capable of driving the electrode **18** upwardly from its position of Fig. 1 into circuit-closing engagement with the other electrode **17**. The actuating means is also capable of driving the movable electrode **18** rapidly downwardly from the closed position to open the interrupter.

When the electrode is driven downwardly to open the interrupter, a circuit-interrupting gap is established between the adjacent ends of the electrodes, and the resulting arc, though quickly extinguished, vaporizes some of the metal of the electrodes. In order to prevent this metallic vapor from condensing on the internal insulating walls of the casing **11**, a metallic shield **25** is provided.

This shield **25** is of a generally tubular configuration and extends along the length of the insulating casing **11** for substantial distances on opposite sides of the gap between the electrodes. The shield **25** is electrically isolated from both the electrodes **17** and **18** and also from ground, or, in other words, it is at a floating potential with respect to the electrodes. This floating relationship or electrical isolation is achieved by relying upon the insulating casing **11** as a supporting structure for the shield **25**. To this end, the ceramic casing **11** is formed from two coaxially-disposed ceramic tubes joined together by a ceramic-to-metal seal which comprises an annular metallic disc **27** sealingly interposed between the adjacent ends of the ceramic tubes. This disc **27** is suitably united, as by welding, to the tubular shield **25** and, thus, supports the shield **25** upon the insulating casing **11**.

In accordance with the present invention, we provide a pair of end shields **30** and **31** which are respectively electrically-connected to the electrodes **17** and **18**. As shown in Fig. 1, these end shields are of cup-shaped, generally-tubular configuration and cooperate with the central floating shield **25** to provide a pair of series-related vacuum gaps **32** and **34** at opposite ends of the central shield **25**. Preferably, these ends shields are welded or otherwise secured to the electrodes **17** and **18**.

Without these end shields, there is a tendency for electrical stresses to become concentrated in the region of the seals **14**. Such stress concentration results not only from the relatively sharp inner peripheral edges of the metallic discs **14***b* but also because of the tendency of an electric field to cencentrate near the boundary between conductive and insulating surfaces. Such stress concentrations tend to encourage breakdowns and are therefore most desirable.

In accordance with our invention, we materially lessen the possibility of such breakdowns by utilizing the end-shields **30** and **31** to transfer the electrical stresses away from the seals **14** and to distribute them over less vulnerable areas of the interrupter insulation. This may be more clearly understood by comparing the interrupter of Fig. 1 with a corresponding interrupter in which the end-shields are omitted, such an interrupter being shown in Fig. 2. Referring to Fig. 2, the dotted lines represent equipotential lines showing the general manner in which the voltage impressed across the interrupter terminals is distributed, for example, in the upper left hand region of the interrupter. It will be observed from Fig. 2 that the equipotential lines are distributed unevenly along the casing **11** and are rather severely concentrated in the region of the end seal **14**. This, of course, results in high electrical stresses in the region of the end seals **14**. With the end-shields present, however, as shown in Fig. 1, the equipotential lines are distributed in a much more uniform manner along the insulating casing **11**, and, particularly, without any material concentration in the region of the end seals. Thus, the end-shields **30** and **31** serve to reduce the voltage gradients in the region of the end-seals **14** and thereby greatly lessen the possibility of breakdowns from the seals.

It will be apparent from Fig. 1, that essentially all straight-line paths which extend from the general region of the arcing gap to the insulating casing **11** are intercepted either by the floating central shield **25** or by the end shields **30**, **31**. This relationship contributes in an important manner toward protecting the interior surfaces of the insulating casing **11** from the build-up of a metallic coating thereon. This follows from the fact that the metallic particles liberated from the electrode tips by arcing tend to travel in generally straight-line paths once they leave the general region of the arcing gap. Our studies of this matter indicate that arcing will produce elevated pressures in the immediate region of the arcing gap, and in this particular region the metallic particles will travel in all directions. But once the particles leave this pressurized region, they travel outwardly therefrom in generally straight-line paths. The shielding **25**, **30**, **31** interposes in essentially all of these paths metallic surfaces upon which these particles condense before they can reach the casing **11**. A small percentage of the metallic particles can bounce off the shields one or possibly several times before finally adhering, but only an insignificant number of such particles can reach the casing **11** due to the tortuous and restricted nature of the gaps **32** and **34**. The fact that the tubular inner end of each end-shield is larger than and also surrounds the adjacent end of the central shield contributes to the desired tortousness of the paths extending through the gaps **32** and **34**. Since substantially all the metallic particles are captured on the metallic shields and are prevented from coating the insulating surfaces, it will be apparent that the shields of Fig. 1 will retain the voltage distribution illustrated by the dotted lines of Fig. 1 without such distribution being substantially changed by the condensation of said particles on the shields.

The end-shields **30** and **31** also serve the very desirable function of shielding the end-caps **12**, **13** and the bellows **20** from the effects of the electric field. This is most desirable because it is extremely difficult to provide these latter parts with surfaces having the degree of smoothness and cleanliness which would otherwise be necessary to assure high dielectric strength. Surface irregularities or the presence of insulating films,

such as oxides, would cause these parts, if unshielded, to represent serious sources of breakdown. Since, in the disclosed interrupter, the voltage gradient in the region of these parts is very low due to the presence of the end-shields, as can be observed from Fig. 1, there is little likelihood of breakdown occurring from these parts. As can be further observed from Fig. 1, the cup-shaped configuration of thes end-shields contributes in an important manner to their effectiveness in electrostatically shielding the end-caps.

The end shields **30** and **31**, as well as the central shield **25**, have smooth, highly-polished surfaces which are free from insulating films. They are preferably constructed of a material such as nickel, which can be subjected to relatively high degassing temperatures without melting. Because the shields are relatively thin, it is not difficult to effect a thorough degassing thereof. The fact that the shields are thoroughly degassed and have polished, film-free surfaces tends to lessen the possibility of breakdowns being initiated therefrom.

The end shields **30**, **31** also minimize the possibility that an arc established at the arcing gap will wander on to the end-caps. Though in nearly all cases arcing is confined to the region of the gap between the electrodes, it will occasionally happen that an arc terminus will escape from this region and wander about seeking to transfer the arc to another region where less energy is required for maintenance of the arc. With an end shield interposed as an obstruction which the arc would be required to circumvent if one terminus were on an end cap, it is extremely unlikely that the required arcing path would represent a region of least energy. Almost invariably, the energy required for such an arcing path would exceed that required if the terminus were located somewhere on the contacts in the volume generally enclosed by the shielding. Thus, with the end-shields **30** and **31** interposed between the end caps and the arcing gap, there is little if any possibility that an arc will be transferred on to the end caps.

Thus, since, for all practical purposes, arcing from the end-caps is prevented, it is possible to more economically prepare the end caps for incorporation into the interrupter. For example, it becomes unnecessary to thoroughly degas the end-caps, as is required with the electrodes and shields. It also becomes unnecessary to provide highly-polished film-free surfaces for the end-caps.

As explained in the aforesaid Crouch application, the presence of the two series-related gaps **32** and **34** minimizes the possibility of a power arc being established from the shielding. In this regard, it has been observed that breakdowns may occur at random in an electrically-stressed gap even though the gap normally has sufficient dielectric strength to successfully withstand this same voltage for extended periods of time. A unique feature of a vacuum gap is that, in many such cases, the gap is capable of recovering its normal dielectric strength within a few microseconds after a breakdown is initiated, thus quickly extinguishing the discharge. The possibility that such a random breakdown will result in a power arc being established from the shielding is minimized in the disclosed interrupter by the presence of the two series-related vacuum gaps **32** and **34**. As explained hereinafter, each of these gaps has a dielectric strength which normally is capable of withstanding the maximum voltage to which the interrupter may be subjected. Should one of these gaps spark-over in the above-described random fashion during or after an opening operation, then the dielectric strength of the other gap is available to prevent complete breakdown of the interrupter, thus precluding the formation of a power arc. Since a breakdown across a single gap does not establish a complete power circuit, no follow current results from such a breakdown, and consequently, the resulting discharge can be quickly extinguished in the vacuum before any harm results to the interrupter.

Other advantages of utilizing a floating central shield, such as the ability of the floating shield to facilitate obtaining a symmetrical electric field for the arcing gap, are set forth in the aforesaid Crouch application, and reference may be had thereto for a more complete description of such advantages. The symmetrical electric field will, however, be discussed in greater detail hereinafter.

The possibility of concurrent breakdown of both gaps **32** and **34** is minimized in the disclosed interrupter by constructing the shields **25**, **30** and **31** in such a manner that the floating shield **25** is at approximately a mid-potential with respect to the electrodes **17** and **18** when the interrupter is in its fully open position. This relationship can be attained in a well-known conventional manner by suitably shaping the shields, by suitably selecting the size of the inter-shield gaps, and by suitably selecting the location at which the mounting flange **27** is supported on the insulating casing **11**. For example, in the disclosed interrupter this relationship is obtained by constructing the two gaps of the same size and configuration and by supporting the mounting flange **27** midway between the terminals of the interrupter. Obviously, these relationships would not be materially changed by the presence of a conductive coating on the internal surface of the shields **25**, **30**, and **31**. Accordingly, the production of such coatings, as a result of arcing, does not significantly vary the potential of the shield **25** relative to the electrodes. Preferably, the size and configuration of each of the inter-shield gaps are of such a nature that each of these gaps has an appreciably greater breakdown strength than the gap between the electrode tips when the electrodes **17**, **18** are in fully-open position. This further minimizes the possibility of both intershield gaps breaking down concurrently. In this regard, if one of the gaps did spark-over, it is extremely unlikely, as explained hereinabove, that the other gap would spark-over before extinction of the discharge at the first gap.

It has been observed that arcing gaps in general have a lower breakdown strength when subjected to voltage of one polarity than when subjected to a voltage of an opposite polarity. In general, it appears that the more non-symmetrical is the electric field in the region of the gap the more pronounced is this polarity effect. Because our central shield **25** is at a generally mid-potential and because the internal structure of the switch is generally symmetrical with respect to a reference plane bisecting the arcing gap between the fully-open electrodes and extending perpendicular thereto, the controlling electric field is generally symmetrical with respect to this reference plane. This symmetrical relationship of the electric field about the interrupting gap makes it possible to largely eliminate the above-described polarity effect, as is described in greater detail in the aforementioned Crouch application. As a result, when used for interrupting alternating-current circuits, the disclosed interrupter is not subject to the unduly prolonged arcing which could result from low breakdown strength during alternate half cycles.

To prevent electric stresses from concentrating near the ends of the shields, these ends are rolled over, as shown at **36**. The resulting improvements in stress distribution materially lessen the likelihood of breakdown occurring from these ends.

Fig. 3 shows a modified arrangement for supporting end-shields of the general type described hereinabove, with similar reference numerals being used to designate corresponding parts. Referring to Fig. 3, it will be noted that the end shield **30** is formed as an integral part of the sealing disc **14*b***. This eliminates the need for welding the end-shield to the electrode **17**, as in Fig. 1. This construction also helps to eliminate the relatively sharp edge which is present in the seal **14** of Fig. 1. Preferably, the end-shield **30** of Fig. 3 extends into close proximity with the electrode **17**, so as to provide an effective obstruction between the end-cap **12** and the arcing gap in the same general manner as the shield **30** of Fig. 1. The shielding arrangement of Fig. 3 is especially suited for interrupters of relatively great length, and, for this reason, the interrupter of Fig. 3 is illustrated as being somewhat longer than that of Fig. 1.

While we have shown and described particular embodiments of our invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from our invention in its broader aspects, and we, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a vacuum circuit interrupter, a generally-tubular casing of insulating material, conductive end caps mounted at opposite ends of said casing, vacuum-tight seals located between said casing and said end caps, a pair of electrodes located within said casing and disposed in spaced-apart relationship during a circuit-interrupting operation to define an arcing gap therebetween, a first generally-tubular metallic shield surrounding said arcing gap and extending along the length of said casing for substantial distances on opposite sides of said arcing gap for intercepting and condensing metallic vapors emitted from said arcing gap, said shield being electrically isolated from both of said electrodes and from ground, said metallic shield having a potential relative to one of said electrodes in open-circuit position which is a predetermined percentage of the potential between said electrodes in open-circuit position, said predetermined percentage being retained without being substantially changed by the condensation of said metallic vapors on said shield even from a time prior to the condensation of said metallic vapors thereon, a pair of generally-tubular metallic end-shields extending from the region of said end caps into proximity with said first shield and cooperating with said first shield to provide a pair of series-related vacuum gaps at opposite ends of the first shield, said end-shields being respectively electrically-connected to said electrodes and being shaped to lower the electrical stresses in the region of said seals in comparison to the stresses which would be present without said end-shields, said three shields being interposed between said arcing gap and essentially all of those insulating surfaces which isolate said electrodes from each other and from said first shield, said three shields coacting to maintain the voltage distribution along said tubular casing substantially unchanged by the condensation of said metallic vapors on said shields even from a time prior to the condensation of said vapors on said shields.

2. The interrupter of claim 1 in which each of said end-shields terminates in a open-end portion which is spaced radially-outward from an adjacent end of said first shield.

3. The interrupter of claim 1 in which said generally-tubular end shields surround said first shield in the region of said inter-shield gaps.

4. The interrupter of claim 1 in which at least one of said seals comprises a radially-extending conductive disc which is integrally united with one of said end-shields.

5. In a vacuum circuit interrupter, a generally-tubular casing of insulating material, conductive end caps mounted at opposite ends of said casing, vacuum-tight seals located between said casing and said end caps, a pair of electrodes located within said casing and dis-

posed in spaced-apart relationship during a circuit-interrupting operation to define an arcing gap therebetween, a first generally-tubular metallic shield surrounding said arcing gap and extending along the length of said casing for substantial distances on opposite sides of said arcing gap for intercepting and condensing metallic vaports emitted from said arcing gap, said shield being electrically isolated from both of said electrodes and from ground, said metallic shield having a potential relative to one of said electrodes in open-circuit position which is a predetermined percentage of the potential between said electrodes in open-circuit position, said predetermined percentage being retained without being substantially changed by the condensation of said metallic vapors on said shield even from a time prior to the condensation of said metallic vapors thereon, a pair of metallic end-shields extending from the region of said end caps into proximity with said first shield and cooperating with said first shield to provide a pair of series-related vacuum gaps at opposite ends of the first shield, the portion of each of said end-shields which is adjacent said first shield being located axially inward of said seals whereby to relieve said seals of electrical stress concentrations, said three shields being interposed between said arcing gap and essentially all of those insulating surfaces which isolate said electrodes from each other, said three shields coacting to maintain the voltage distribution along said tubular casing substantially unchanged by the condensation of said metallic vapors on said shields even from a time prior to the condensation of said vapors on said shields.

6. In a vacuum circuit interrupter, a generally-tubular casing of insulating material, conductive end caps mounted at opposite ends of said casing, vacuum-tight seals provided between said casing and said end caps, a pair of electrodes located within said casing and disposed in spaced-apart relationship during a circuit-interrupting operation to define an arcing gap therebetween, a first generally tubular metallic shield surrounding said arcing gap and extending along the length of said casing for substantial distances on opposite sides of said arcing gap, said first shield having a metallic internal surface which acts to intercept and condense metallic vapors emitted from said arcing gap, said shield being electrically isolated from both of said electrodes and from ground, said internal surface being metallic even prior to the condensation of said metallic vapors thereon and having a potential relative to one of said electrodes in open-circuit position which is a predetermined percentage of the potential between said electrodes in open-circuit position, said predetermined percentage being retained without being substantially changed by the condensation of said metallic vapors on said shield even from a time prior to the condensation of said metallic vapors thereon, a pair of conductive end-shields cooperating with said first shield to provide a pair of series-related vacuum gaps at opposite ends of said first shield, said end shields being respectively electrically-connected to said electrodes and being shaped to lower the electrical stresses in the region of said seals in comparison to the stresses which would be present without said end shields, said three shields being so located that they are interposed between said arcing gap and essentially all of the internal insulating surfaces of said insulating casing, said three shields coacting to maintain the voltage distribution along said tubular casing substantially unchanged by the condensation of said metallic vapors on said shields even from a time prior to the condensation of said vapors on said shields.

7. In a vacuum circuit interrupter, a highly evacuated vacuum-tight envelope comprises a generally-tubular casing of insulating material and a pair of end caps disposed at the ends of said casing, a pair of electrodes located within said insulating casing and disposed in spaced-apart relationship during a circuit-interrupting operation to define an arcing gap therebetween, a first generally-tubular metallic shield surrounding said arcing gap and extending along the length of said casing for substantial distances on opposite sides of said arcing gap, said first shield having a metallic inner surface which acts to intercept and condense metallic vapors emitted from said arcing gap, said shield being electrically isolated from both of said electrodes and from ground, said metallic shield having a potential relative to one of said electrodes in open-circuit position which is a predetermined percentage of the potential between said electrodes in open-circuit position, said predetermined percentage being retained without being substantially changed by the condensation of said metallic vapors on said shield even from a time prior to the condensation of said metallic vapors thereon, a pair of metallic end-shields respectively electrically connected to said electrodes and cooperating with said first shield to define a pair of series-related vacuum gaps at opposite ends of the first shield, said three shields being so located that essentially all straight-line paths which extend from the region of said arcing gap to said insulating casing intersect at least one of said shields, and three shields coacting to maintain the voltage distribution along said tubular casing substantially unchanged by the condensation of said metallic vapors on said shields even from a time prior to the condensation of said vapors on said shields.

8. The interrupter of claim 7 in which said end-shields are of a generally-tubular configuration and extend from the region of said end caps into proximity with said first shield, said end-shields surrounding said first shield in the region of said inter-shield gaps.

9. The interrupter of claim 7 in which said end-shields are of a generally-tubular, cup-shaped configuration, each end-shield terminating in an open-end portion which is spaced radially-outward from an adjacent end of said first shield.

10. The interrupter of claim 1 in which said three shields coact despite vapor condensation of said shields to maintain a substantially uniform voltage distribution along the portion of said tubular casing extending from the general region of one of said seals to the general region of the other of said seals while said electrodes are in spaced-apart relationship.

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