

[54] **HYBRID CIRCUIT INTERRUPTER**

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[22] Filed: **July 25, 1973**

[21] Appl. No.: **382,421**

[52] U.S. Cl. **200/144 B, 200/148 B, 200/150 E**

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

[58] Field of Search..... **200/144 B, 146 R, 150 E,
200/148 B**

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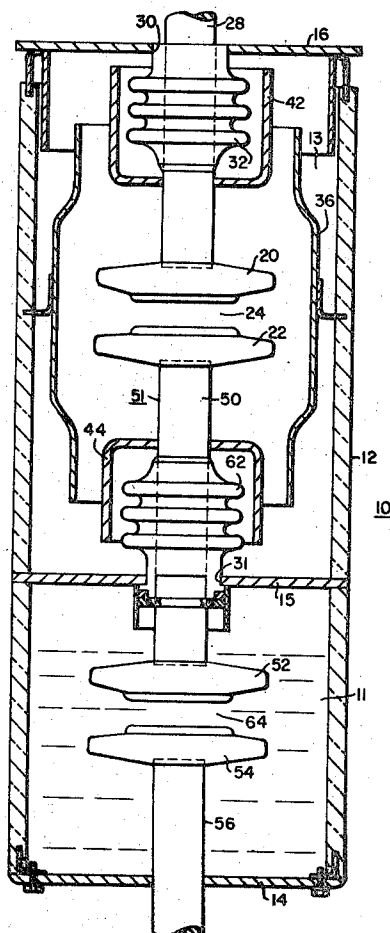
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[57] **ABSTRACT**

A hybrid circuit interrupter is provided, having a set of contacts in a vacuum environment and another set

of contacts in an insulating fluid, such as oil, or gas or the like, environment connected in series and disposed in one compact enclosure. During closing the contacts in the insulating liquid or gas are closed after the contacts in the vacuum have closed. During an opening operation the contacts in the vacuum chamber separate first and then the contacts in the chamber containing the insulating fluid or gas separate. Thus, the circuit is completed in the insulating liquid or gas environment and the circuit is opened in the vacuum environment. With the hybrid circuit interrupter fully opened two serially related gaps are provided in the circuit interrupter. One of the contacts in the chamber containing the insulating fluid or gas is rigidly mechanically connected to one of the contacts in the vacuum chamber. A single operating stroke opens or closes the hybrid circuit interrupter. The contacts used in the vacuum chamber can be constructed from material having low chopping characteristics so that high voltages are not induced in the electrical circuit during interruption. The contacts used in the chamber containing the insulating fluid, such as oil or gas, can be constructed from material having good non-welding characteristics so as not to weld upon interrupter closing and to be easily opened without the use of complicated and expensive weld breaking mechanisms.

11 Claims, 4 Drawing Figures



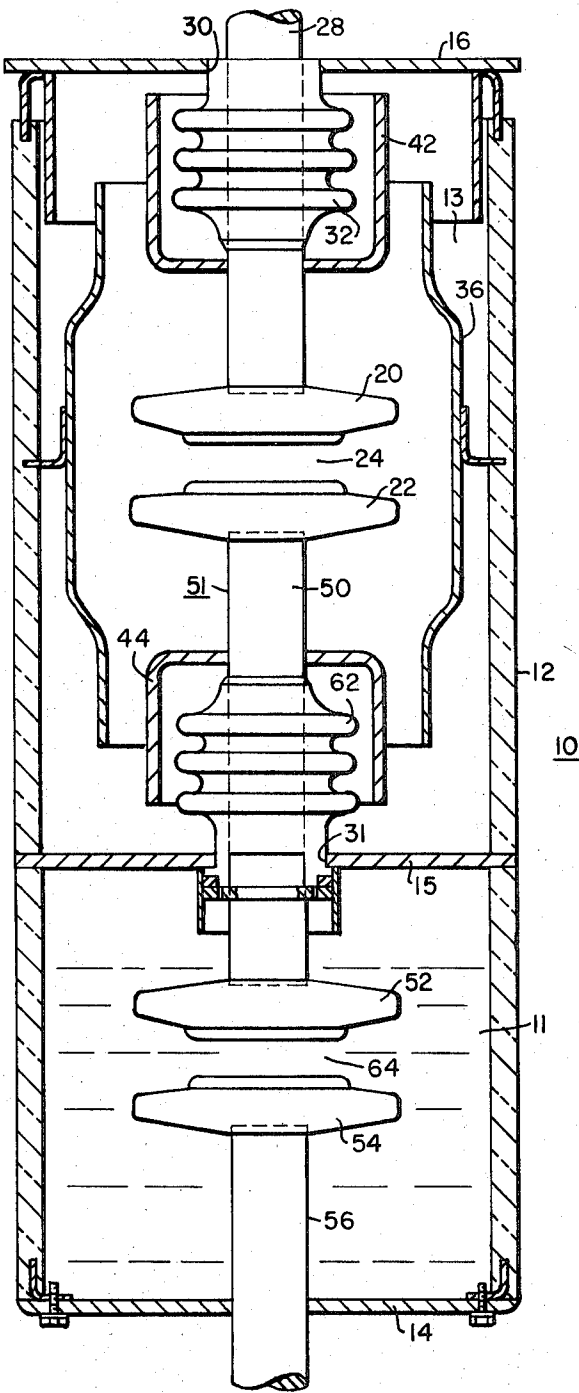


FIG. 1

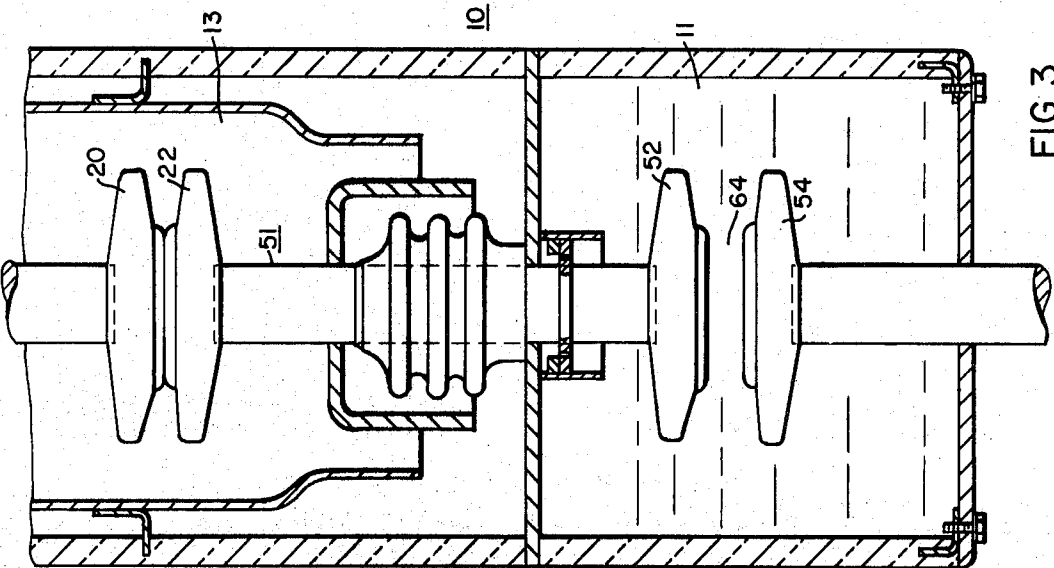


FIG. 3

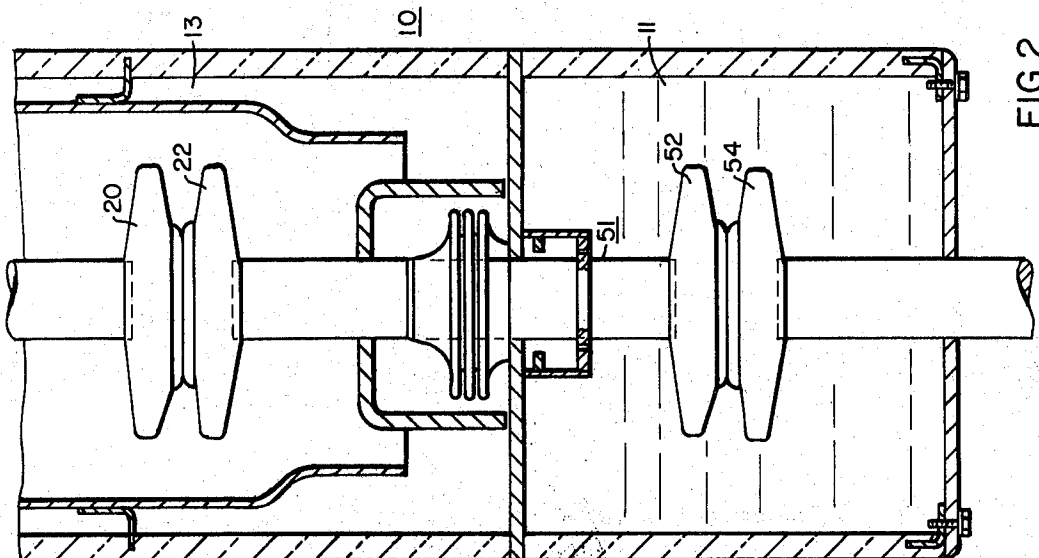


FIG. 2

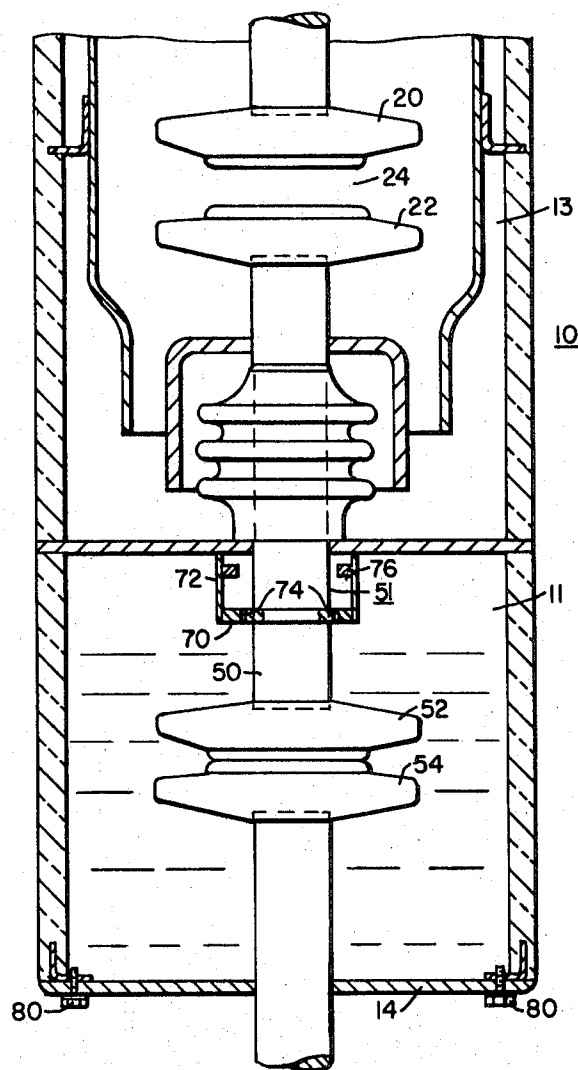


FIG. 4

HYBRID CIRCUIT INTERRUPTER

BACKGROUND OF THE INVENTION

The present invention relates to circuit interrupters and more particularly to an interrupter in which the circuit is completed in a chamber containing an insulating fluid, such as oil or SF₆ (sulfur hexafluoride), and the circuit is opened in a vacuum chamber. The circuit interrupter disclosed utilizes the principle of closing on contacts in an environment where the contacts do not weld on closing and opening in a vacuum environment on contacts having good chopping characteristics so as to minimize current chopping upon opening.

Contact welding on closing and current chopping on opening are two problems associated with vacuum interrupters. Contact welding causes rapid contact erosion and necessitates an expensive release mechanism to insure that the contacts will open when required. While current chopping induces undesirable high voltages in the circuit being interrupted. Other types of interrupters such as oil and SF₆ or the like do not experience contact welding on closing but generally experience rapid contact erosion on opening. Conversely, vacuum switches experience little contact erosion on opening due to their excellent arc extinguishing properties.

A typical prior art type vacuum circuit interrupter generally comprises an evacuated insulation envelope. The contacts are movable between a closed position in which the contacts are engaged and an open position where the contacts are separated and an arcing gap is established therebetween. An arc is initiated between the contact surfaces when the contacts move into or out of engagement of the circuit in which the interrupter is energized. As the contacts are brought together the arcs that are formed melt some of the metallic contact material. After the contacts are brought together under high pressure, engagement welds may be formed between the contact surfaces due to the melted contact material formed during arcing. Current surges also occur in the first few milliseconds of contact closing and these can also cause contact welding. The magnitude of the force required to break the welds so that the contacts can be opened depends upon many factors including the arc voltage, the current, the contact area, and the contact material. These welds are objectionable since they interfere with easy movement of the separable contacts and may result in failure of the vacuum interrupter to open.

Another difficulty that is encountered with some prior art contacts in vacuum interrupters is that the materials used have an excessive tendency to chop under low current conditions. This sharp chop in current can induce extremely high voltages across inductive devices connected in the circuit being interrupted and such over voltages can lead to destruction of the circuit components. For an effective circuit interrupter there should not be an excessive current chop on the circuit opening. One of the best materials for opening is copper, but this welds easily on contact closing. It is felt that the present invention has significant advantages over prior art circuit interrupters in that the circuit is closed on a material and in an environment, such as oil or SF₆, that assures there will be no contact welding and the circuit is opened on a material such as copper

in a vacuum environment to assure rapid interruption without current chopping.

SUMMARY OF THE INVENTION

This invention discloses a hybrid circuit interrupter construction which effectively closes in an environment which will provide good non-welding characteristics and opens in an environment such as a vacuum on a material such as copper, which does not cause excessive current chopping and which has good interrupting characteristics. Essentially the contacts of a vacuum interrupter are connected in series and controlled in sequence with another set of contacts disposed in an insulating fluid such as oil, SF₆, or the like. The vacuum contacts close first without current flowing thus there can be no welding of the vacuum chamber contacts and then the contacts in the insulating liquid fluid or gas close to complete the circuit without contact welding. On opening, the vacuum contacts open first to interrupt the current without current chopping and little contact erosion, and then the contacts in the insulating liquid fluid or gas part without having to interrupt current and therefore experience no contact erosion. In this way, the vacuum contacts can never weld and hardly erode and the contacts in the other insulating media would experience little contact erosion.

In one embodiment of the invention both sets of contacts are disposed in a single insulation enclosure. This improves operation of the vacuum interrupter and the insulating fluid interrupter. One operator stroke, without other mechanical linkage can open and close both sets of contacts. Closing in oil, SF₆, or the like and opening in a vacuum can be accomplished by using two circuit breakers. However, this would be uneconomical, involve longer opening and closing times, and present synchronization problems. In the disclosed invention a first chamber having a vacuum and a second chamber containing an insulating fluid, such as oil, SF₆, or the like are formed within an insulating housing. The housing can be of a generally tubular construction with a vacuum chamber formed at one end of the housing and the oil or SF₆ chamber formed at the other end of the housing. Both ends of the housing are closed by metallic end caps. The vacuum chamber is separated from the chamber containing the insulating medium by a metallic separator. A fixed contact is supported by a conducting rod which is attached to one end of the insulating housing. A first movable contact is attached to a movable operating rod which extends through the other end of the insulating housing. Disposed between the fixed contact and the first movable contact is a centrally disposed contact assembly comprising a second movable contact disposed in the vacuum chamber, a third movable contact disposed in the chamber containing the insulating fluid and a movable conducting rod connecting the second and third movable contacts. The second and third movable contacts and the movable conducting rod are rigidly connected so as to form the centrally disposed contacts assembly.

As the circuit interrupter is closed the first movable contact moves into engagement with the second movable contact and moves the centrally disposed contact assembly so that the third movable contact engages the fixed contact and completes an electrical path through the circuit interrupter. On interrupter opening the first movable contact initially separates from the second movable contact and then the third movable contact

separates from the fixed contact so that gaps are formed between the first movable contact and the second movable contact and between the third movable contact and the fixed contact. Thus when the circuit interrupter is in the open position two serially related gaps are formed in the circuit interrupter.

The circuit interrupter disclosed in the instant application has several advantages over some prior art interrupters, such as having no welding of the vacuum contacts and thus requiring no special operating mechanism to break contact welds. There is very little erosion of the contacts and by proper selection of contact material used in the vacuum chamber, current chopping on opening can be held to a minimum. The chamber containing an insulating fluid such as oil or a gas such as SF_6 can be constructed to be easily opened so that these contacts can be inspected and maintained. A high voltage rating is possible since two complete serially related breaks are present when the interrupter is in the opened position. Only one operator is required to open both sets of contacts and full contact pressure is maintained on both sets of contacts when in the closed position. In one compact design, the contact opening advantages of vacuum interrupters are combined with the contact closing advantages of other types of circuit breakers.

It is an object of this invention to provide a circuit interrupter which completes an electric circuit through a set of contacts disposed in an insulating fluid or gas and opens the electric circuit through a set of contacts disposed in a vacuum.

It is an object of this invention to provide a circuit interrupter having two serially related sets of contacts disposed in a single compact housing; one set of contacts being disposed in a vacuum environment and the other set of contacts being disposed in an insulating fluid or gas environment.

It is another object of this invention to provide a circuit interrupter having two sets of contacts in series which can be opened or closed by a single operator stroke, and which maintains full contact pressure on both sets of contacts.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages of the present invention will be readily apparent upon reading the following description taken in conjunction with the drawings in which:

FIG. 1 is a vertical section view of a circuit interrupter in the open position embodying the teachings of the present invention;

FIG. 2 is a view similar to FIG. 1 showing the circuit interrupter in the fully closed position;

FIG. 3 is a view of the circuit interrupter shown in FIG. 1 with the contacts in an intermediate closed position; and,

FIG. 4 is a view of a portion of the circuit interrupter shown in FIG. 1 with the contacts in an intermediate open position.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and more particularly to FIG. 1, there is shown a circuit interrupter 10 embodying the teachings of the present invention. The circuit interrupter 10 comprises an insulating envelope 12 formed of glass or a suitable ceramic material and a

pair of metallic end caps 14 and 16. A central metallic partition 15 divides the insulating envelope 12 into two chambers, 11 and 13, and renders the top portion of insulating envelope 12 between end cap 16 and partition 15 vacuum tight. The top portion of insulating envelope 12 is thus formed into a vacuum chamber 13. The vacuum chamber 13 under normal operating conditions is lower than 10^{-4} torr so that the mean free path of electrons will be longer than the potential breakdown distance within the vacuum chamber 13.

Disposed within the vacuum chamber 13 are a first movable contact 20 and a second movable contact 22. As shown in FIG. 1, when these contacts 20 and 22 are separated there is an arcing gap 24 formed therebetween. The top movable contact 20 is movable into and out of engagement with contact 22. Contact 20 is attached to a conducting operating rod 28. The conducting operating rod 28 is suitably mounted for movement along the longitudinal axis of the insulating envelope 12. The movable operating rod 28 projects through an opening 30 in end cap 16 and is connected to suitable operating means (not shown) which moves contact 20 generally along the longitudinal axis of insulating envelope 12.

As shown in FIG. 1, a flexible metallic bellows 32 is secured in sealing relationship at its respective opposite ends to movable operating rod 28 and to the opening 30 in end cap 16. The flexible metal bellows 32 provides a seal about the rod 28 to allow for movement of the rod 28 without impairing the vacuum inside vacuum chamber 13.

Movable contact 22 is secured to connecting rod 50, which is formed from a material having good electrical conduction properties, by suitable means such as welding or brazing. Conductive connecting rod 50 is suitably mounted for movement along the longitudinal axis of the tubular insulating envelope 12. The movable connecting rod 50 projects through an opening 31 in partition member 15 and extends into chamber 11 at the bottom side of insulating envelope 12. Partition member 15 separates vacuum chamber 13 from a second chamber 11, formed at the bottom of insulating envelope 12 and containing an insulating fluid such as oil or gas such as SF_6 . Disposed within chamber 11 are a third movable contact 52 and a stationary contact 54.

As shown in FIG. 1, a second flexible metallic bellows 62 is secured in sealing relationship at its respective opposite ends to conducting movable connecting rod 50 and opening 31 in the partition member 15. The flexible metal bellows 62 provides a seal about the rod 50 to allow for movement of the rod 50 along the longitudinal axis of insulating envelope 12 without impairing the vacuum inside vacuum chamber 13. Movable contact 52 is rigidly secured to the end of connecting rod 50, which projects into chamber 11, by suitable means such as welding or brazing. The stationary contact 54 is secured to a conducting support rod 56 by suitable means such as welding or brazing. The support rod 56 passes through and is secured to end cap 16 by suitable means, such as welding or brazing.

Coupled to the free end of the operating rod 28, suitable actuating means (not shown) is provided for driving the movable contact 20 into engagement with movable contact 22 which in turn moves connecting rod 50 and attached contact 52 into engagement with stationary contacts 54 so as to close the circuit interrupter 10.

While in the closed position a continuous current path is provided through the circuit interrupter 10. The continuous current path extends through conducting rod 56, stationary contact 54, contact 52, connecting rod 50, contact 22, contact 20 and conducting operating rod 28. The actuating means is also capable of returning the movable contact 20 to its open position so as to open the interrupter 10. With the circuit interrupter in the fully opened position as shown in FIG. 1 a gap 64 exists between contacts 52 and 54 and another gap 24 exists between contacts 20 and 22. Thus in the fully opened position, two serially related gaps, 24 and 64, exist in the interrupter 10 giving a high voltage withstand level.

Due to the short distances to be moved and the high dielectric strength of vacuum, circuit interrupter 10 can be opened very rapidly, when compared with an oil or gas type circuit breaker. When during current interruption circuit interrupter 10 opens, contacts 20 and 22 disposed within the vacuum chamber 13 separate at the beginning of circuit interruption and a metallic arc initiates between the separated contacts 20 and 22. The arc formed across gap 24 serves as a vehicle for current conduction until the arc is extinguished. In an alternating current circuit the arc is usually extinguished near the first current zero of the alternating current wave. The arc that is established across the arcing gap 24 between the contacts 20 and 22 when they are opened, vaporizes and melts some of the contact material. The vapors are dispersed from the arcing gap 24 towards the inside of the insulating envelope 12 which forms a portion of vacuum chamber 13. The internal surfaces of the insulating envelope 12 within vacuum chamber 13 are protected from the condensation of the arc generated metallic vapor and particles thereon by means of a tubular metallic shield 36. The tubular metallic shield 36 is supported on the insulating envelope 12 and preferably electrically isolated from both end cap 16 and partition member 15. This shield acts to intercept and condense arc generated metallic vapor and particles before they can reach the internal surfaces of the vacuum chamber 13. A cup-shaped shield 42 is attached to the movable operating rod 28 and partially surrounds flexible metal bellows 32 to prevent the bellows 32 from being bombarded by arc generated metallic vapors and particles. At the other end of the vacuum chamber another cup shaped shield 44 is attached to the conducting movable connecting rod 50 and surrounds a portion of flexible metal bellows 62 to prevent bellows 62 from being bombarded by arc generated metallic vapors or particles.

As shown in FIG. 2, when the circuit interrupter 10 is in the fully closed position, contact 20 is in engagement with contact 22 and contact 52 is in engagement with contact 54. During initial closing of circuit interrupter 10 as shown in FIG. 3, contact 20 initially engages contact 22 and as operating rod 20 continues to move to the left the centrally disposed contact assembly 51 comprising contacts 22, and 52, and connecting rod 50 are moved to the left until contact 52 engages stationary contact 54 and a continuous current path is established through interrupter 10. As can be seen in FIG. 3, contacts 20 and 22 during initial closing are in engagement while a gap 64 still exists between contacts 52 and 54. Due to the presence of gap 64 there can be no current flowing through the interrupter 10 when contacts 20 and 22 engage during initial closing of in-

terrupter 10. Thus, since contacts 20 and 22, which are disposed in the vacuum chamber 13, close under no current conditions there can be no welding of contacts 20 and 22 during interrupter 10 closing. Since there is no welding of the contacts 20 and 22 disposed in the vacuum chamber 13 during circuit interrupter 10 closing, special weld break mechanisms are not required to open the interrupter 10 and separate contacts 20 and 22.

Final closing of the circuit through interrupter 10 is thus accomplished as the centrally disposed contact assembly 51 is moved to the left, and contacts 52 and 54 which are disposed in chamber 11 engage. Chamber 11 is filled with an insulating fluid, such as oil, SF₆ or the like, and contacts closing in these environments do not weld. Thus, the interrupter 10 can be closed as shown in FIG. 2 without the danger of either contacts 20 and 22 or contacts 52 and 54 being welded together. Thus, the interrupter 10 can be opened and closed with a simplified operating mechanism, not requiring expensive weld breaking apparatus. It should be noted that since contact sets 20-22 and 52-54 when in engagement are serially related the full contact pressure applied by the operating mechanism is provided between each pair of contacts 20-22 and 52-54. Only one operation is necessary to close both set of contacts and no synchronization problems are present. Also, all contacts can be closed without the use of complicated interlinking mechanisms as would be required if a separate vacuum interrupter and oil interrupter were connected serially.

The pressure internal of chamber 11 acts on the bellows 62 and the centrally disposed contact assembly 51 to urge the centrally disposed contact assembly 51 to the open position when the operating mechanism moves contact 20 to the open position.

During an opening operation contact 20 initially separates from contact 22 as shown in FIG. 4. Due to the high dielectric strength of the vacuum in chamber 13 and a quick recovery time the current through interrupter 10 is normally interrupted at the first current zero, after contacts 20 and 22 separate. Thus the circuit is interrupted in a vacuum environment which has excellent arc extinguishing properties. Thus, there is very little arcing during circuit opening in chamber 11, which would cause rapid deterioration of contacts 52 and 54. After the operating mechanism moves contact 20 to the open position as shown in FIG. 4, the internal pressure of chamber 11 upon the centrally disposed contact assembly 51 urges the contact assembly 51 to the open position. As shown in FIG. 4, a dashpot and stop arrangement can be added to limit the speed and travel of contact assembly 51. A disc 70 can be attached to connecting rod 50 and fit inside a tubular member 72 so as to act as a dashpot and limit the opening speed of contacts 52 and 54. Orifices 74 may be provided in disc 70 to determine the speed at which contact 52 will move to the open position. Stop 76 may also be provided to limit the travel of contact assembly 51. The stop 76 will limit the travel of contact assembly 51 so that two gaps 24 and 64 will be maintained internal of interrupter 10. By varying the opening speed of the oil or gas disposed contacts 52 and 54 the interruption can be shared by vacuum contacts 20 and 22 and the oil or gas contact 52 and 54. This can aid in controlling current chopping.

The end cap 14 is attached to the insulating envelope 12 by suitable means such as bolts 80 which provide for easy removal of end cap 14. Allowing end cap 14 to be easily removed permits ready access to chamber 11 and allows for maintenance and inspection of contacts 52 and 54. Thus maintenance of the non-vacuum part of interrupter 10 is facilitated. It can be seen that an interrupter is provided having a construction in which the opening advantages of vacuum interrupters are combined with the closing advantage of other type circuit interrupters. Since there is no problem with contact welding a simplified operating mechanism is sufficient without the necessity of complicated and expensive release and weld breaking mechanisms. Contacts 20 and 22 can be formed of a material having good current chopping characteristics such as copper to assure that upon contact interruption there will be minimal current chop. High voltage ratings are possible with the structure taught in this invention since two interrupting gaps are placed in series in interrupter 10. The simplified operating mechanism can open and close both pairs of contacts 20, 22 and 52, 54 without additional leverage or mechanical linkage. With the construction taught in this invention there is no synchronization problem with the sequence of opening and closing of the interrupter 10.

What is claimed is:

1. A circuit interrupter comprising:

a vacuum chamber being vacuum tight and having a high vacuum formed therein;

a first set of contacts disposed within said vacuum chamber and being movable between an open position and a closed position;

an insulating fluid chamber containing an insulating fluid having a high dielectric strength;

a second set of contacts disposed in said insulating fluid chamber and being movable between an open position and a closed position;

said first set of contacts being connected in series with said second set of contacts so that said first set of contacts and said second set of contacts both must be closed to close said circuit interrupter; and;

operating means for closing and opening said circuit interrupter whereby during a closing operation of said circuit interrupter said first set of contacts close and then after a time delay said second set of contacts close and during an opening operation of said circuit interrupter said first set of contacts opens and then after a time delay said second set of contacts opens.

2. A circuit interrupter comprising:

a vacuum chamber;

a first movable contact disposed within said vacuum chamber;

a second movable contact disposed within said vacuum chamber;

said first movable contact and said second movable contact being relatively movable between a closed position in which said first movable contact and said second movable contact are in engagement and an open position in which said first movable contact is separated from said second movable contact to establish a gap therebetween;

an insulating fluid chamber containing an insulating fluid having a high dielectric strength;

a stationary contact disposed within said insulating fluid chamber;

a third movable contact disposed within said insulating fluid chamber and being movable between a closed position in engagement with said stationary contacts and an open position spaced from said stationary contacts to establish a gap therebetween;

electrical conductor means connecting said second movable contact to said third movable contact;

said first movable contact, said second movable contacts, said third movable contact, and said stationary contact being connected in series;

operating means for moving the contacts of said circuit interrupter between an open position, in which said first movable contact is spaced from said second movable contact and said third movable contact is spaced from stationary contact, and a closed position, in which said first movable contact engages said second movable contact and said third movable contact engages said stationary contact, providing a continuous current path through said circuit interrupter; and wherein,

said operating means during a closing operation of said circuit interrupter initially causes said first movable contact to engage said second movable contact and later causes said third movable contact to engage said stationary contact, and during an opening operation of said circuit interrupter initially causes said first movable contact to separate from said second movable contact and later causes said third movable contact to separate from said stationary contact to provide two serially related gaps in said circuit interrupter.

3. A circuit interrupter as claimed in claim 2 comprising;

an insulating housing;

said insulating housing forming a portion of said vacuum chamber and a portion of said insulating fluid chamber.

4. A circuit interrupter as claimed in claim 2 wherein:

said insulating housing comprises a generally tubular shaped portion formed from an insulating material; and

partition means disposed in said insulating tubular portion of said insulating housing perpendicular to the longitudinal axis of said insulating housing to divide said housing into a first portion which forms part of said vacuum chamber and a second portion which forms part of said insulating fluid chamber.

5. A circuit interrupter as claimed in claim 2, wherein said electrical conductor means comprises a rigid electrical conductor.

6. A circuit interrupter as claimed in claim 5, wherein said rigid electrical conductor is formed as a generally rod-shaped member having said second movable contact attached rigidly to one end and said third movable contact attached rigidly to said respective opposite ends so as to rigidly position said second movable contact with respect to said third movable contact.

7. A circuit interrupter as claimed in claim 6, wherein said second movable contacts and said third movable contacts and said rigid electrical conducting means are formed as an integral part.

8. A circuit interrupter as claimed in claim 2, wherein said first movable contact and said movable contact are

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formed from a material having good non-chopping characteristics and said third movable contact and said stationary contacts are formed from a material having good non-welding characteristics.

9. A circuit interrupter as claimed in claim 2, wherein said insulating fluid chamber contains an insulating fluid comprising a gas.

10. A circuit interrupter as claimed in claim 2, wherein said first movable contact and said second

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movable contact are formed from copper.

11. A circuit interrupter as claimed in claim 2, wherein said insulating fluid chamber comprises an access cover and removable fastening means to hold said access cover in position so that access cover can be easily removed to provide access to said stationary contact and said third contact.

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