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Rathbun

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[54] **FAIL SAFE VACUUM TYPE CIRCUIT INTERRUPTER AND ASSOCIATED LOAD CURRENT TAP CHANGER FOR ELECTRIC INDUCTION APPARATUS**

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[73] Assignee: **General Electric Company**

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[52] **U.S. Cl.** .....**323/43.5 R,** 200/144 B, 323/45

[51] **Int. Cl.**.....**H02p 13/06,** H01h 9/30

[58] **Field of Search** .....200/144 B, 81 R, 84 B; 337/152, 222, 246; 323/43.5 R, 45

[56] **References Cited**

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[57] **ABSTRACT**

A load current tap changer for electric power transformers includes a vacuum type arcing-duty current interrupter immersed in dielectric fluid and biased to closed position by differential pressure. Overtravel limit switch means is actuated to shunt the vacuum arc gap upon excessive contact separation due to loss of vacuum and contact bias force. Limiting contact overtravel also disables the tap selector driving means.

12 Claims, 3 Drawing Figures

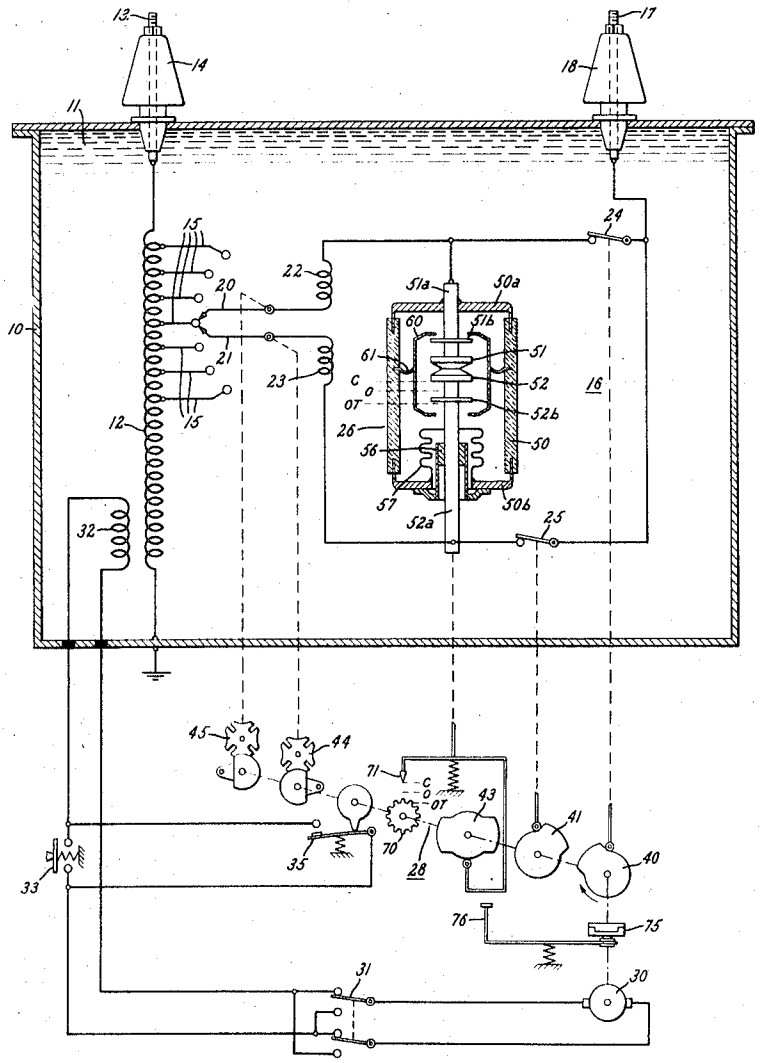


Fig. 1.

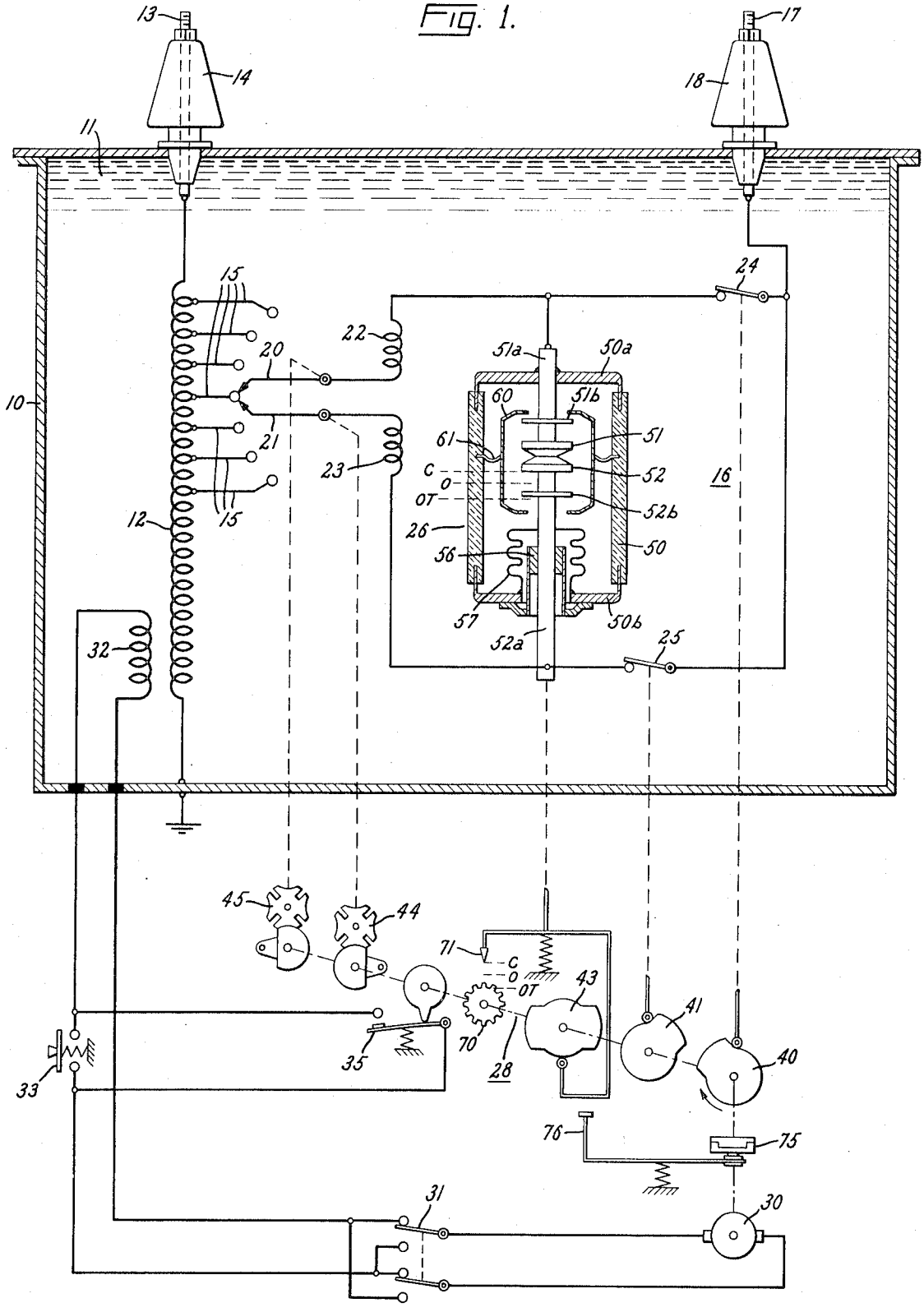

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51a
50a
60
51b
61
51
C
O
OT
52
52b
26
56
50
57
52a
50b
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71
43
41
40
35
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76
75
31
30

Fig. 2.

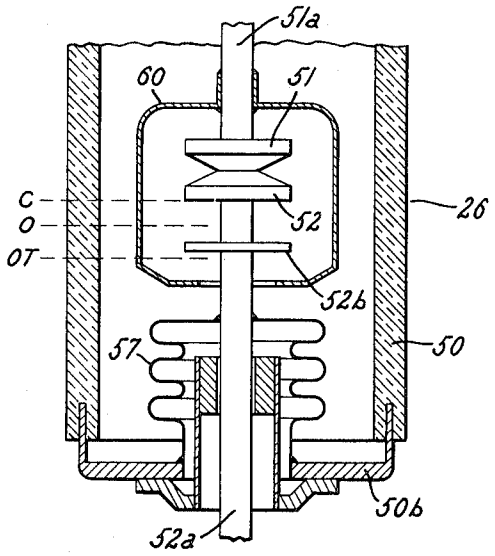
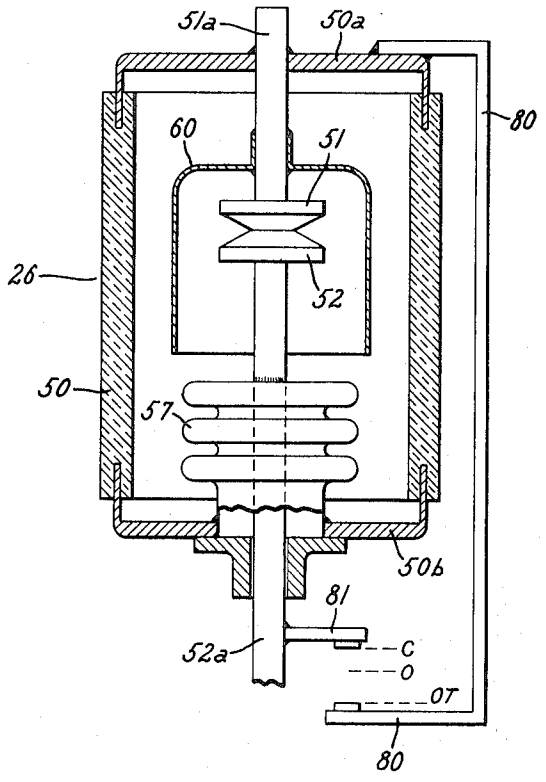

51a
60
51
C
O
OT
52
26
52b
57
50
50b
52a

Fig. 3.


51a
50a
80
60
51
26
52
50
57
50b
81
52a
C
O
OT
80

FAIL SAFE VACUUM TYPE CIRCUIT INTERRUPTER AND ASSOCIATED LOAD CURRENT TAP CHANGER FOR ELECTRIC INDUCTION APPARATUS

My invention relates to protective means for vacuum type circuit interrupting devices and for load current tap changing apparatus including such devices, and more particularly to fail-safe means for preventing damage to such apparatus and devices in the event of significant loss of vacuum in an interrupting device immersed in a body of liquid. Published prior art presently known to applicant and concerning apparatus of this general type is illustrated in the following U.S. Pat. Nos.: 3,265,840 to Luehring; 3,404,247 to Glassanos; and 3,472,981 to McCarty et al.

Vacuum type electric current interrupting devices of high interrupting capacity are useful in electric switches and circuit breakers of all types, and are presently available in voltage and current ratings capable of interrupting power flow at voltages and frequencies commonly used in commercial and industrial distribution and transmission systems. In most applications the vacuum interrupting device is likely to be located in an ambient atmosphere of air, so that even a large leak in the evacuated envelope can do no more than fill the envelope with air or gas at ambient pressure. Under such conditions the device may fail to interrupt current, but the contained gas or air is not likely to build up sufficient pressure to fracture the envelope. In certain special applications it is desirable to immerse a vacuum interrupting device in a surrounding ambient liquid. In such locations it is possible that a leak of appreciable size and time duration will admit to the switch envelope a pool of liquid sufficient, if heated excessively by an arc, to develop a bursting pressure.

One special application where it is desirable to immerse a vacuum interrupter in a surrounding ambient liquid is in load tap changing apparatus for power transformers or other electric induction apparatus. Such transformers are usually immersed in a dielectric liquid such as oil or askeril, and the tap changing equipment is also liquid immersed. However, the tap changer ordinarily includes an arc current interrupting device which has been located in a separate liquid filled compartment to avoid contamination of the main body of transformer oil as a result of arching at the switch. To accommodate the mechanical interconnection of the arching switch with the transfer contacts and other switches in a tap changing apparatus, it has been customary to locate the entire tap changing apparatus in the separate liquid filled compartment. This requires all the tap leads from the transformer winding to be brought out from the main body of the transformer to the tap changing compartment. In high voltage apparatus this is an expensive procedure in both labor and material costs.

It would be desirable, if possible, to locate all the tap changing apparatus for high voltage power transformers, reactors and the like directly within the main enclosing tank and immersed in the main body of transformer oil or other dielectric liquid. This economical arrangement does become possible when the arc interrupting switch is of the vacuum type. With the entire tap changing apparatus so located, the tap leads need not be brought out of the tank, and no separate tap changing compartment need be provided. Even if a separate compartment is otherwise desirable, a vacuum interrupting device is advantageous in a load tap changer in order to avoid contamination of the oil in that compartment and the consequent frequent maintenance. On the other hand a vacuum interrupting device so located in the dielectric liquid of an associated electrical apparatus should not be permitted to develop leaks sufficiently large to admit liquid to the switch envelope. Even in the absence of further damage, a fractured interrupter would so contaminate the dielectric liquid that expensive and time consuming maintenance work would be required.

Accordingly it is a principal object of my invention to provide improved leak responsive protective means for vacuum type electric circuit interrupters and associated load current tap changing apparatus.

It is a more particular object of my invention to provide means for preventing long continuance of arcing in a vacuum interrupting device subjected to abnormal increase in internal pressure.

It is still a further object of my invention to provide a vacuum type electric circuit interrupter provided internally with means responsive to abnormal increase of internal pressure to short circuit the contacts and terminate arcing therebetween.

In carrying out my invention in one preferred embodiment, I utilize tap changing apparatus of the type including two movable tap selector switches connected in parallel circuit relation to a common line terminal and adapted to be moved in sequential step by step manner from one tap position to an adjacent tap position. The parallel branch circuit connections of the selector switches preferably include current limiting reactors and are adapted to be interrupted sequentially prior to stepping movement of each associated tap selector switch. For such interruption I utilize a vacuum type circuit interrupter, either one in each branch circuit or a single interrupter connected to be switched into the branch circuits sequentially during the interrupting interval of each circuit.

A vacuum interrupting device of the evacuated envelope type is usually a normally closed contact device by reason of the fact that the movable contact rod is sealed to the enclosing envelope by means of a flexible or deformable wall portion of the envelope (such as a metallic bellows), and external pressure on such wall portion biases the movable contact to engaging position. Thus actuating force applied to the movable contact rod to move it to disengaging position must act against the closing bias of the bellows or other flexible seal. If the actuating mechanism for the movable contact permits overtravel of the movable contact beyond its normal open circuit position abnormal overtravel will result from some predetermined diminution or reversal of differential pressure on opposite sides of the flexible wall seal.

In such a vacuum type load current tap changing apparatus I utilize overtravel, or abnormal opening movement, of the movable vacuum interrupter contact resulting from abnormally high internal pressure in the evacuated envelope to effect contacting engagement of a shunting device either within or outside the envelope, thereby to extinguish arcing between the contacts and prevent further build up of pressure. The abnormal

pressure effective to actuate the shunting device is preferably less than a pressure which would rupture the switch envelope. In a preferred embodiment of my invention I utilize a metallic vapor shield within the vacuum interrupter envelope as the contact shunting device by so mounting the shield that when engaged by the movable contact in abnormal overtravel it completes a shunt circuit between the contacts. Such a shield may be normally connected electrically to one of the contacts or insulatingly mounted in electrostatically floating relationship.

In order to prevent further tap changing movement of the selector contacts with the vacuum interrupting device shunted and inoperable, and thus to eliminate arcing at the tap selector contacts, I also provide means actuated by abnormal overtravel of the vacuum switch contact to block the tap changing mechanism or disable the motor drive for the mechanism, or both.

My invention will be more fully understood and its several objects and advantages further appreciated by referring now to the following detailed specifications taken in conjunction with the accompanying drawing wherein:

FIG. 1 is a schematic illustration of a transformer load tap changing apparatus including a vacuum type circuit interrupting device and embodying my invention; and

FIGS. 2 and 3 are fragmentary cross-sectional views of vacuum interrupting devices illustrating other embodiments of contact shunting devices which may be utilized in the apparatus of FIG. 1.

Referring now to the drawing, I have illustrated at FIG. 1 a high voltage autotransformer of the liquid immersed type including a tank or enclosure **10** substantially filled with insulating oil or other dielectric fluid **11** and having positioned therein a winding **12**. The transformer winding **12** is grounded at its low voltage end, as by connection to the tank **10**, and at its other end it is connected to a high voltage line terminal conductor **13** which passes out of the tank through an insulating bushing **14**. The high voltage end of the autotransformer winding is provided with a plurality of selectable voltage taps each having a terminal contact **15**. A selected one of the tap terminals is adapted to be connected through a load tap changing apparatus **16** to a secondary line terminal conductor **17** disposed in an insulating bushing **18**. The load tap changing apparatus designated generally by the reference number **16** comprises a pair of movable tap selector contacts or fingers **20, 21**, associated pairs of current limiting reactors **22, 23** and transfer switches **24, 25**, a vacuum interrupting switch **26** and a motor driven cycle timer (designated generally as **28**) for controlling the operation of the foregoing tap selector contacts and switches.

The tap selector circuit of the apparatus **16** is of a well known type. This circuit provides two parallel current paths, or branch circuits, between any selected tap terminal **15** and the common secondary line terminal **17**, each branch circuit includes one of the tap selector contacts **20, 21** in series with one of the reactors **22, 23** and one of the transfer switches **24, 25**. Each transfer switch **24, 25** has a line contact connected to the terminal **17** and a load contact connected to one of the tap selector contacts **20, 21**. The arcing duty vacuum interrupting device **26** is connected between the parallel branch circuits on the load sides of the transfer switches **24, 25** so that either transfer switch when opened is shunted by the vacuum interrupter and the other transfer switch.

The cycle timer **28** is selectably operable in either direction to effect sequential stepping movement of the tap selector fingers **20, 21** progressively in either direction along the group of transformer tap terminals **15**. The cycle timer is driven selectively in either direction by a motor **30** through a reversing switch **31** from a suitable source of control voltage shown as a tertiary winding **32** on the transformer **12**. When energized the timer starts from a normal rest position and operates for a single complete cycle to effect a single stepping movement of both tap selector contacts **20** and **21**. The motor energizing circuit includes a normally open starting switch **33** which for the purpose of illustration may be considered to be manually operable. The cycle timer includes a motor holding and limit switch **35** connected in parallel circuit relation across the starting switch **33** and arranged to deenergize the motor at the end of a single cycle in either direction of operation.

The cycle timer **28** comprises a pair of cams **40, 41** arranged to open the transfer switches **24** and **25** sequentially in either direction of operation, and a cam **43** arranged to open the arcing contact switch **26** at two spaced apart intervals during each cycle. A pair of Geneva gears **44, 45** driven by the cycle timer is connected to actuate the tap selector contacts **21** and **20** in sequential relation at appropriate times during a cycle of operation in either direction.

A typical single cycle of operation of the tap changing apparatus described above takes place as follows: If the starting switch **33** is closed momentarily to energize the motor **30**, the cycle timer begins to rotate in a selected direction (assume clockwise) as determined by the reversing switch **31**. Immediately upon initiation of operation, the holding and limit switch **35** closes to maintain motor energization for a full cycle. During this cycle of operation the cam **40** first opens the transfer switch **24**, thereby to substitute the contacts of the arcing contact switch **26** for the switch **24** in the branch circuit through the tap selector contact **20** and reactor **22**. Following opening of the transfer switch **24**, the contacts of the arcing vacuum switch **26** are opened by the cam **43**, thereby to interrupt current through the tap selector contact **20**. Thereafter the Geneva gear **45** moves the tap selector contact **20** to the next adjacent tap terminal **15** in the selected direction. Following this operation the cam **43** again closes the contacts of the arcing contact vacuum switch **26**, and cam **40** closes transfer switch **24**; thereafter the cam **41** opens the transfer switch **25**. After opening of the switch **25** the cam **43** again opens the vacuum switch **26** thereby to interrupt current through the tap selector contact **21** and the reactor **23**. While the tap contact **21** is deenergized, the Geneva gear **44** moves that tap contact to the next adjacent tap terminal **15** to which the tap contact **20** was previously moved. Thereafter the arcing contact vacuum switch **26** is again closed by the cam **43**, and the transfer switch **25** is reclosed by the cam **41**. This completes a single cycle of operation and the limit switch **35** thereupon deenergizes the motor **30**. It will be evident to those skilled in the art that operation in the reverse direction is entirely similar.

Reference will now be had more particularly to the arcing contact vacuum interrupter 26 connected between the parallel tap selector branch circuits. This circuit interrupter comprises an evacuated envelope 50, illustrated as a cylinder of insulating material such as glass having metallic end closure caps 50*a* and 50*b* and having mounted therein a pair of separable contacts 51, 52. The vacuum switch contacts 51, 52 are mounted, respectively, on the juxtaposed ends of axially aligned fixed and movable contact rods 51*a* and 52*a*. Contact rod 51*a* is fixed to the metal end cap 50*a* and the contact rod 52*a* is slidably mounted in a bearing 56 which is mounted upon the end cap 50*b*. The slidable contact rod 52*a* extends through the end cap 50*b* and is sealed to the end cap by means of a flexible metallic bellows 57. The bellows 57 is connected at one end to the end wall 50*b* of envelope 50 and at the other end to the contact rod 52*a* and thus constitutes a flexible portion of the envelope wall.

The bearing 56 does not provide a hermetic seal so that the interior of the bellows 57 is exposed to ambient pressure outside the switch envelope 50. In the example illustrated this is the pressure of the surrounding liquid body 11 and is ordinarily approximately atmospheric pressure. Since this external pressure is greater than the very low pressure within the highly evacuated envelope 50 it exerts upon the flexible bellows 57 a force tending to expand the bellows and move the switch contact 52 to its engaged or circuit closing position as shown in the drawing. Thus to separate the contacts 51, 52 and to open the vacuum switch it is necessary to forceably pull the contact rod 52*a* outward (or downward as shown in the drawing) and to this end the opening cam 43 on the cycle timer 28 is illustrated as applying a downward force upon its cam follower. In the drawing I have illustrated by dotted lines adjacent the movable contact 52 the closed, or engaged, position (C) of contact 52, the normal open or disengaged position (O) of the contact 52, and an overtravel or abnormally displaced open position (OT) of the contact 52. Abnormal displacement to position OT will be more fully described hereinafter.

Mounted coaxially within the vacuum interrupter envelope 50 I have shown a cylindrical metallic vapor shield 60 with the contacts 51, 52 and contact rods 51*a*, 52*a* in the central arcing region of the envelope. The shield 60 is mounted upon the insulating envelope 50 and normally not electrically connected to either of the contacts 51, 52 so that it is in electrostatically floating relation with respect to the contact potential. A shield mounting member 61 between the shield 60 and the envelope 50 is designed to be frangible or otherwise deformable under forces to be described hereinafter, but normally holds the shield 60 in fixed position out of engagement with the vacuum switch contacts and rods in both engaged and normal disengaged positions of the contacts.

In the embodiment of my invention herein described by way of illustration the electrically conductive metallic vapor shield 60 and the frangible, or otherwise deformable, shield mounting 61 is utilized to provide a conductive shunt connection across the arc gap and between the contacts 51, 52 in the event the movable contact 52 is actuated to its abnormally displaced overtravel position OT. For this purpose the shield is provided at each end with in-turned end collars approaching but not engaging the aligned contact rods 51*a*, 52*a* and positioned for engagement with conductive interference detents or projections 51*b*, 52*b*, respectively, on the contact rods.

It will now be evident to those skilled in the art that in the normal cyclic operation of tap changing apparatus described above the vacuum interrupter contacts 51 and 52 open and close recurrently without engagement of any contact parts with the enclosing vapor shield 60. In the event, however, that an abnormal increase in pressure occurs within the vacuum switch envelope 50, as for example because of a leak in one or more of the sealed joints constituting the envelope, the closing bias exerted by the bellows 57 will be partially or fully overcome depending upon the extent of internal pressure increase. Of course even without any leak, and in the absence of foreign material within the evacuated envelope, internal pressure increases in normal circuit opening operation as the result of arcing between the contacts and the presence of metal vapor. Such normal increase in pressure is not sufficient, to drive the movable contact 52 beyond the normal contact opening position O. At some predetermined high pressure, however, contact 52 will be driven to its overtravel position OT. Preferably the abnormally high pressure effective to produce such overtravel is less than that which would rupture the envelope 50.

In the event of leakage in the vacuum envelope 50, foreign material such as gas or liquid within the envelope will result in an increase in internal pressure which, without arcing, may or may not be sufficient to reverse the closing bias on the bellows 57. If, however, such increased internal pressure is of sufficient magnitude that further increase due to contact arcing does reverse the normal closing bias the movable contact rod 52*a* will be driven in the opening direction beyond its normal open position O and toward the abnormally displaced overtravel position OT. In moving to this position the contact rod projection 52*b* engages the lower end collar of the conductive shield 60, and if the opening pressure is sufficient the shield mounting 61 will be broken or otherwise deformed and the shield 60 moved downwardly into engagement with the contact rod projection 51*b*. Thus by excessive opening movement of the contact rod 52*b* the metallic shield 60 is brought into shunting relation with the arc gap and operates as a limit switch to bridge the separated contacts 51, 52 and terminate arcing within the envelope 50. By this action the vacuum switch 26 is protected against further increase in internal pressure and against possible rupturing forces.

In the event of abnormal overpressure within the vacuum switch 26 and consequent failure of the switch to interrupt current it is desirable to protect the tap changing apparatus by disabling the cycle timer 28 and the stepping selector contacts 20, 21. For this purpose I have shown a blocking gear 70 on the cycle timer shaft which is adapted to be engaged and held in fixed position by a detent 71 actuated by the movable contact rod 52*a*. It will be understood that the detent 71 engages the blocking gear 70 only when the contact rod 52*a* is in its abnormally displaced overtravel position. On the drawing at FIG. 1 I have indicated by dotted lines the positions of detent 71 corresponding to the closed (C) open (O) and overtravel (OT) positions of the movable contact rod 52*a*.

As an alternate, or additional, means for disabling the cycle timer **28** I have shown also a clutch **75** between the driving motor **30** and the cycle timer shaft. By a schematic coupling connection **76** I have illustrated the clutch **75** as being actuated to open position only when the movable contact rod **52***a* is in its abnormal overtravel position.

At FIG. **2** I have illustrated another embodiment of overtravel shunting device operable by a vacuum interruption contact and operable in the apparatus shown at FIG. **1**. In the vacuum interrupter shown at FIG. **2** the conductive vapor shield **60** is physically mounted upon and electrically connected at its upper end to the fixed contact rod **51***a*. An in-turned end collar at the lower end of the shield is positioned to be engaged by the movable contact **52** only in its overtravel position, as indicated on the drawing.

At FIG. **3** I have shown still another form of vacuum interrupter in which a shunting switch external to the evacuated envelope **50** comprises a fixed contact **80** connected electrically to the fixed vacuum contact **51** and a movable contact **81** mounted on the movable contact rod **52***a*. As indicated the limit switch contacts **80, 81** are positioned to engage only in the overtravel position OT of the contact rod **52***a*.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects; and I, therefore, intend herein to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. A load current tap changer for electrical apparatus having a plurality of tap terminals and a line terminal comprising, a pair of movable tap selector contacts mounted for sequential stepping movement in either direction between adjacent tap terminals, a pair of parallel branch circuits each connecting one of said tap selector contacts to said line terminal, each said branch circuit including a transfer switch having separable line and load contacts, a vacuum type circuit interrupting device connected between the load contacts of said transfer switches and including separable arcing contacts within an evacuated envelope, said arcing contacts being biased into engagement by differential pressure within and without said envelope, means actuating said transfer switches alternately to open position thereby to transfer said arcing contacts into one said branch circuit, means actuating said arcing contacts to normal disengaged positions separated by an arc gap thereby to interrupt current through said one branch circuit prior to stepping movement of the associated tap selector contact, said actuating means and at least one said arcing contact being free to overtravel beyond its normal disengaged position in response to abnormal increase of pressure within said envelope thereby to increase the length of said arc gap, and limiting contact means engageable upon predetermined overtravel and abnormal separation of said arcing contacts to conductively shunt said arc gap.

2. A tap changer according to claim **1** wherein said limiting contact means is mounted within said envelope and actuated to engaged position in response to predetermined abnormal overtravel of at least one of said arcing contacts.

3. A tap changer according to claim **1** wherein said limiting contact means comprises a cylindrical metal shield mounted within said envelope and enclosing said arc gap in coaxial radial spaced relation and a contact means actuated by at least one of said arcing contacts to engage said shield in response to abnormal overtravel of said one arcing contact.

4. A tap changer according to claim **3** wherein one said arcing contact is fixed and the other movable, normally fixed deformable mounting means electrostatically isolated from said arcing contacts positions said shield normally beyond engagement with either of said arcing contacts and said movable arcing contact is positioned to engage said shield upon abnormal overtravel contact movement and move said shield into engagement with said fixed arcing contact.

5. A tap changer according to claim **3** wherein one said arcing contact is fixed and the other movable, said shield is mounted upon and electrically connected to the fixed arcing contact, and conductive means on the movable arcing contact engages said shield upon predetermined abnormal contact opening movement.

6. A tap changer according to claim **1** wherein said arcing contacts comprise a pair of axially aligned conductive rods one of which is fixed to said envelope and the other is movably mounted upon a flexible wall portion of said envelope, and said limiting contact means comprises a fixed contact and a movable contact actuated by said movable contact rod.

7. A tap changer according to claim **6** wherein said limiting contact means is positioned outside said evacuated envelope.

8. A tap changer according to claim **1** additionally including driving means for actuating said tap selector contacts and means operable upon abnormal separation of said arcing contacts to disable said driving means.

9. A tap changer according to claim **8** wherein said driving means includes alternately and intermittently rotatable gearing connected to actuate said tap selector contacts and said disabling means comprises blocking means engageable positively to lock said gearing against movement.

10. A tap changer according to claim **8** wherein said driving means includes a rotatable electric motor and said disabling means comprises a clutch for disconnecting said motor from said tap selector contacts.

11. The combination with a tap changer according to claim **1** of an electric induction apparatus including said tap terminals and said line terminal, a common housing for said induction apparatus and said vacuum interrupting device, and a body of dielectric fluid in said housing at least partially immersing said induction apparatus and said vacuum interrupting device.

12. In combination, an electric power transformer having a plurality of tap terminals and a line terminal, an enclosing housing for said transformer, a body of dielectric liquid in said housing substantially immersing said transformer, and the tap changer of claim **1** connected between said line terminal and said tap terminals with said vacuum interrupting device immersed in said dielectric liquid.

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